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The efficacy of biodiversity and ecosystem assessment approaches for informing a regenerative approach to built development

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Abstract

The built environment, even at its "greenest," inevitably entails changing ecosystem structure and function. Multiple sustainable development tools and approaches are available to reduce environmental harm from built development. However, the reality that society exists within fully integrated socioecological systems, wholly interdependent on supporting ecosystems, is not yet adequately represented in regulation or supporting tools. Regenerative development seeks to address this interdependence in part by improving the health of supporting socioecological systems through the development process. We demonstrate the relevance of a series of approaches—Local Nature-Related Planning Policy (LNRPP), Biodiversity Net Gain (BNG), the Environmental Benefits from Nature Tool (EBN Tool), Nature Assessment Tool for Urban and Rural Environments (NATURE Tool), and Rapid Assessment of Wetland Ecosystem Services+ (RAWES+)—for their ability to meet their stated aims and objectives and how these relate to wider regenerative themes. A comparative analysis of the five approaches is done by applying them to a practical case study site, resulting in policy- and practice-relevant learning and recommendations. The research reveals current gaps in methodology, which can lead to adverse outcomes for sustainability. This is particularly clear for the spatial and temporal scales across which each approach operates. In addition, this research discusses the inherent limitations of taking a reductionist approach to examining complex systems. *Integr Environ Assess Manag* 2024;20:248–262. © 2023 The Authors. *Integrated Environmental Assessment and Management* published by Wiley Periodicals LLC on behalf of Society of Environmental Toxicology & Chemistry (SETAC).

KEYWORDS: Assessment tools; Biodiversity Net Gain; Ecosystem services; Regenerative development

INTRODUCTION

Humanity is completely dependent on the functioning of natural ecosystems through flows of goods and services, including regulating and supporting processes conferring resilience to both human and natural disturbances (IPBES, 2019; Millennium Ecosystem Assessment, 2005). Nonetheless, human development has and continues to substantially perturb planetary ecosystems at scales from the local to the global (Bradshaw et al., 2021), with radical implications for climate change (IPCC, 2007) and the supportive and regulating capacities of ecosystems (Everard et al., 2021; Millennium Ecosystem Assessment, 2005).

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Built development in a systems context

Built development addresses multiple, linked human needs, including habitation, transport, employment, education, and entertainment. However, this is generally at net cost to habitat, environmental integrity, and system functioning both at development site scale and more remotely through demands for water, energy, food, transport, waste arisings, and other services (Midgley, 2012; Reed, 2007). As the built environment occurs within fully integrated socioecological systems, it is wholly interdependent with supporting ecosystems. However, legacy regulations and supporting tools do not yet reflect this systemic reality.

Reed (2007) presents several framings in the transition from "business as usual" to regenerative built development. Traditional approaches focus on reducing environmental harm, emphasizing relative improvement through technical efficiency in "high-performance design" and "green design" (e.g., Leadership in Energy and Environmental Design [LEED], Building Research Establishment Environmental Assessment Method [BREEAM], etc.) or "sustainable design," aimed at taking the relative improvements of green

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design to the point at which harm is removed altogether (Reed, 2007). These approaches have contributed materially to the understanding of building-related environmental impacts but fail to incorporate the more complex, systemic values present in socioecological systems (Cole, 2012; Gou & Xie, 2017; Zhang et al., 2015). Recent literature therefore argues for a paradigmatic shift toward a more regenerative approach to the built environment (Orova & Reith, 2021; Reed, 2007), based on the foundation of an ecological worldview (du Plessis & Brandon, 2015; Mang & Reed, 2012). This ecological worldview and its associated regenerative paradigms differ substantially from the mechanistic perspective from which traditional approaches to sustainability have emerged. For example, where the mechanistic approach generates understanding by reducing complex problems and solutions to their constituent parts (du Plessis, 2012; Everard, 2022; Mang & Reed, 2012), the ecological worldview takes a whole systems approach (Camrass, 2021; Cole, 2012; du Plessis & Brandon, 2015; Mang & Reed, 2012).

There are multiple definitions and approaches to the application of regenerative thinking in the built environment (Craft et al., 2021). The following four key themes occur repeatedly in the literature:

- Systems thinking/living systems approach (Camrass, 2021; Cole, 2012; Craft et al., 2021; Gibbons et al., 2018; Reed, 2007): Living systems thinking requires an engagement with the complex interactions between parts of the socioecological systems rather than just a collection of individual parts.
- Importance of "place" (Benne & Mang, 2015; Camrass, 2021; Cole, 2012; du Plessis, 2012; Gibbons et al., 2018; Reed, 2007): Designers should recognize the importance of the socioecological context when envisioning a project's potential in relation to the system in which it is nested (Benne & Mang, 2015).
- Adding positive value (in contrast to damage reduction; Camrass, 2021; Cole, 2012; du Plessis, 2012; Gibbons et al., 2018; Pedersen Zari, 2012; Reed, 2007): Development contributes toward strengthened context-specific socioecological systems.
- Co-evolution between sociocultural and ecological systems (Camrass, 2021; Cole et al., 2013; Craft et al., 2021; du Plessis, 2012; Gibbons et al., 2018): Regenerative development "suggests a relationship that builds, rather than diminishes, social and natural capitals" (Cole et al., 2013, p. 238).

Tools for sustainable built development

Many built environment policies and tools address elements of the new regenerative paradigm outlined above. Examples from the UK include policies such as mandatory Biodiversity Net Gain (BNG) for development projects (in England) being introduced by the UK Environment Act (HM Government, 2021) and commitment under the UK Government's 25-year Environment Plan (Department of Environment, Food and Rural Affairs, 2018) to move toward greater environmental net gain, both seeking improvement rather than neutrality of their host socioecological systems.

Nonetheless, most legacy sustainability assessment tools sit predominantly within reductive (Gasparatos, 2010; Sala et al., 2015) and often economic (instrumental values) framings (James, 2015; Small et al., 2017). It is crucial to understand how the methodological foundations of tools affect their outcome when applied in practice, because any differences can influence conclusions drawn from their application.

The purpose of this study

This study explores how the methodological approaches underpinning a selection of UK-relevant built environment sustainability tools affect their analyses. This is tested in the context of a "real world" development case study: Dickenson's Field in the English county of Rutland. A proposal for development at Dickenson's Field entails the construction of an environmental education center on a "greenfield" site of permanent grassland of mostly good condition, also incorporating habitat diversification to address improvements for nature identified by the national nature conservation agency, Natural England.

The five selected ecosystem-based assessment schemes are: Local Nature-Related Planning Policy (LNRPP), BNG, the Environmental Benefits from Nature Tool (EBN Tool), Nature Assessment Tool for Urban and Rural Environments (NATURE Tool), and Rapid Assessment of Wetland Ecosystem Services+ (RAWES+). Parallel analyses using these five approaches allows identification of their relative strengths and weaknesses focusing particularly on their relationship with regenerative principles and how they are shaped by differing methodological positions. Understanding how the methods used by current tools affect their utility, and how this differs from the foundations of regenerative thinking, can inform integration of regenerative aspirations and principles into current and future tools (Camrass, 2021).

METHODS

Assessment tool and/or approach selection

Assessment tools and/or approaches were selected according to the following criteria:

- Completely free to access.
- Primarily focused on the environmental base of sustainability, over social or economic aspects. This excludes many commonly used tools such as BREEAM or LEED, which conform to a "triple bottom line" approach wherein natural capital can be substituted for social or economic capital.
- Promotes and/or measures one or more of the regenerative themes (listed).
- Designed for UK use (or designed for wider use but have been used in a UK context).

- Represent different stages of Reed's (2007) evolution of approaches to environmental sustainability within the built environment (from "Green" to "Reconciliatory").

Tools were tested to see if they meet their own stated aims/intentions, determined by examining the framing documentation of each tool and/or approach.

Features of selected tools and approaches

Selected tools and approaches and details of application to the case study are summarized in Table 1.

Dickenson's Field and development aspirations

The selected assessment tools and/or approaches were applied to proposed development at the case study site: Dickenson's Field. Data supporting tool use included a preexisting baseline ecological assessment, site plans, Natural England advice, publicly available data, and peer-reviewed literature. Due to Covid-19 lockdowns when the research was undertaken, the authors were unable to visit the site in person, although several of the authors had visited the site in a prior capacity. Dickenson's Field comprises an approximately 2.2-ha greenfield site in the county of Rutland, England. Findings relating to how the relative methodological differences between the tools affect their ability to address regenerative themes should be applicable irrespective of geographical boundaries. However, an English site was selected because several tools are designed exclusively for England. The Dickenson's Field site overlooks Rutland Water (a large reservoir that is also an SSSI and RAMSAR site) to the south, and borders Burley and Rushpit Woods SSSI to the west. (SSSIs are Sites of Special Scientific Interest under nature conservation UK legislation.) Despite its proximity to several designated sites, Dickenson's Field itself is not subject to any nature conservation designations.

The planned development entailed construction of an ecological training center on a small proportion of the site (0.26 ha), with enhancement of the currently uniform grassland habitat including diversification of habitats to increase the site's biological diversity and educational value consistent with advice from Natural England (including desired enhancement of bordering habitat and the addition of a pond). Additional local biodiversity targets and biodiversity and ecosystem service (ES)-enhancing interventions, such as installation of owl and bat boxes, hibernacula, and beehives, were also incorporated into development plans. The intent was to manage small areas of low- and moderate-condition grassland to upgrade their condition and improve a small area of hedging with traditional hedge-laying techniques. The site layout and associated habitat types pre- and postdevelopment are illustrated in Figure 1.

In predevelopment condition, Dickenson's Field predominantly comprises seminatural grassland of good quality that has never been subjected to agrochemical application but has been managed for hay production. Although not explicitly managed for wildlife, low and/or no agrochemical inputs are likely to encourage grassland biodiversity. The development was seen as an opportunity to improve the site's biodiversity through an active land management plan (including targeted conservation grazing, traditional hedge laying, and diversification of habitat) inherently designed to provide both ecological and wider socioeconomic benefits outside the constraints of normal commercial considerations. The unusual, proenvironmental intent of development at Dickenson's Field provides an interesting proxy site to test the scope and limitations of selected tools. The relative areas of each habitat type (pre- and postdevelopment) are shown in Table 2.

Development at the time of writing is in the preplanning phase and has not achieved planning permission, or broken ground, although some ecological enhancement measures have been started.

RESULTS

Summary of outputs from application of selected tools and/or approaches

The results of the five assessment methods tested at Dickenson's Field vary dramatically, depending on the different emphases within each method, revealing difficulties inherent in making clear-cut environmental decisions during development. First, the development project is assessed as likely to meet several local biodiversity planning objectives, while likely to fail others. The project follows Natural England's advice; however, evaluation of BNG using the Defra Metric tool indicates a 12.39% reduction in habitat units.

The RAWES+, NATURE Tool, and the EBN Tool also give contrasting accounts of the impacts of the development on ESs across the site. Table 3 shows the relative change in ES provision between pre- and postdevelopment scenarios in these three ES-focused tools, with agreement between all three tools only present across three of the shared ES categories, and agreement where service provision has changed only present in the "Education" service.

More detailed results from each approach are contained in Section 1 of the Supporting Information.

Performance of selected tools and/or approaches performed against their stated targets

The five assessment tools and/or approaches varied in their stated intent. They also varied in the degree to which these stated intents were met in their application.

Local Nature-Related Planning Policy (LNRPP). Multiple individual policies targeting different aspects of the environment within the local planning system lack a clear overarching aim or purpose. However, within the ecological framing of this article, the following relevant aim was identified from the Core Strategy Development Plan Document (CSDPD):

- "Conditions for biodiversity will be maintained and improved" with priority given to "local aims and targets

TABLE 1 Features of selected built development assessment tools/approaches

Local Nature-Related Planning Policy (LNRPP)

- Local planning policy guiding and/or assessing new build development were reviewed in conjunction with the preapplication plans for Dickenson's Field (Denizen Works, 2021). Guidance included the Rutland Core Strategy Development Plan Document (CSDPD; Rutland County Council, 2011); the Leicestershire, Leicester, and Rutland Biodiversity Action Plan (Timms, 2016); and preapplication project-specific advice from Natural England (letter ref:2021/0477/PRE).

Biodiversity Net Gain (BNG)

- Biodiversity Net Gain (or loss) was calculated using Defra Metric (3.0; Panks et al., 2021), a tool based on the proxy of habitat. Habitat units, Hedgerow units, and River units are generated from predetermined scores for different habitat types (taken from the standardized UK Habitat Classification System), combined with size of habitat parcel and quality of habitat. When new habitat is created, or existing habitat enhanced, multipliers are used to incorporate the risks of habitat change and time taken for new and/or enhanced habitat to reach target condition. Where habitat creation off-site is used to compensate for habitat loss on-site, a multiplier is used to account for the distance of the new habitat from the original site, although no off-site habitat creation was planned as mitigation for proposed development at Dickenson's Field.

The Environmental Benefits from Nature Tool (EBN Tool)

- The Environmental Benefits from Nature Tool (Beta v. 2; Smith et al., 2021a) was used to quantify ES potential units, assessing gains or losses between pre- to postdevelopment scenarios on Dickenson's Field. The EBN Tool works in conjunction with the Defra Metric but, unlike BNG, is a scoping tool and is not intended to give specific answers or a threshold that must be passed. The EBN Tool works in a fashion similar to the Defra Metric, with scores for habitat type modified by a series of multipliers. Each habitat type has a set of baseline scores for each of 18 listed ecosystem services (ESs) across provisioning, regulating, and cultural service categories. These scores are then placed against multipliers based on the questions asked for each ES (e.g., slope gradient is used to inform the erosion protection) and against established multipliers for the time taken for a new habitat to reach target condition for ES provision as well as the risk of it not reaching that condition. The EBN Tool assesses at Basic, Standard, or Advanced levels: Dickenson's Field was assessed under the advanced level, requiring data in 44 fields for each parcel of land inside the redline boundary.

Nature Assessment Tool for Urban and Rural Environments (NATURE Tool)

- The NATURE Tool (Hölzinger et al., 2021) was used to calculate change score and potential score in “Service or Benefit” across 23 categories. It also calculates monetary and CO_2e values for some services. The change score indicates a planned development's natural capital performance (as potential to supply ES) compared with the predevelopment baseline. Like the EBN Tool, the NATURE Tool calculates service and/or benefit change scores using data on habitat areas, assigning different baseline scores to each habitat type for each service and benefit. These scores are combined with delivery risk multipliers. Further multipliers are applied, determined by the questions asked for each ES. For example, the level of nature designation is used to inform a sense of place. The percentage of a site's maximum potential benefit and/or ES score is assessed by dividing the score for the baseline habitat with a theoretical maximum score achievable by replacing this with the highest-rated habitat for each service and/or benefit (considering delivery risk multipliers). The NATURE Tool can be used as a scoping tool, but it also allows the input of specific policy priorities, which can result in a pass or fail assessment.

Rapid Assessment of Wetland Ecosystem Services+ (RAWES+)

- The RAWES+ approach (Cianchi et al., 2023) is an adaptation of the RAWES approach to assessment of ESs adopted by the RAMSAR Convention (RRC-EA, 2020). RAWES+ uses a semiquantitative approach to capture and integrate different types of knowledge, both qualitative and quantitative, appropriate to the differing value systems through which ESs in the four Millennium Ecosystem Assessment (2005) categories (provisioning, regulating, cultural, and supporting) are realized. Additional, context-specific services can also be added where contextually relevant: in the Dickenson's Field case study, a context-specific cultural service of “Nature targets” was added comparing pre- and postdevelopment scenarios with local nature/species/biodiversity targets. RAWES and the modified RAWES+ approaches therefore differ from the EBN Tool and NATURE Tool by not using habitat-specific baseline scores or multipliers. Desk- and field-based evidence is used to assign a relative significance score for each ES ranging from “significantly positive” (++) to “significantly negative” (−−) or "unknown" (?); as outlined below, the RAWES+ modification doing this for each of the range of geographical scales over which benefits and/or disbenefits are realized. The modified RAWES+ methodology is described in Cianchi et al. (2023). Relative significance scores can be statistically transformed (as outlined below) and summed to calculate an Ecosystem Service Index (ESI) score. Ecosystem service indices can be calculated for all services combined, for each ES category, and/or for each geographical range.

Assigned importance	Significantly positive	Positive	Negative	Significantly negative	Unknown
RAWES+ importance score	++	+	−	−−	?
Numerical value for ESI calculation	0.25	0.1	−0.1	−0.25	Remove from analysis

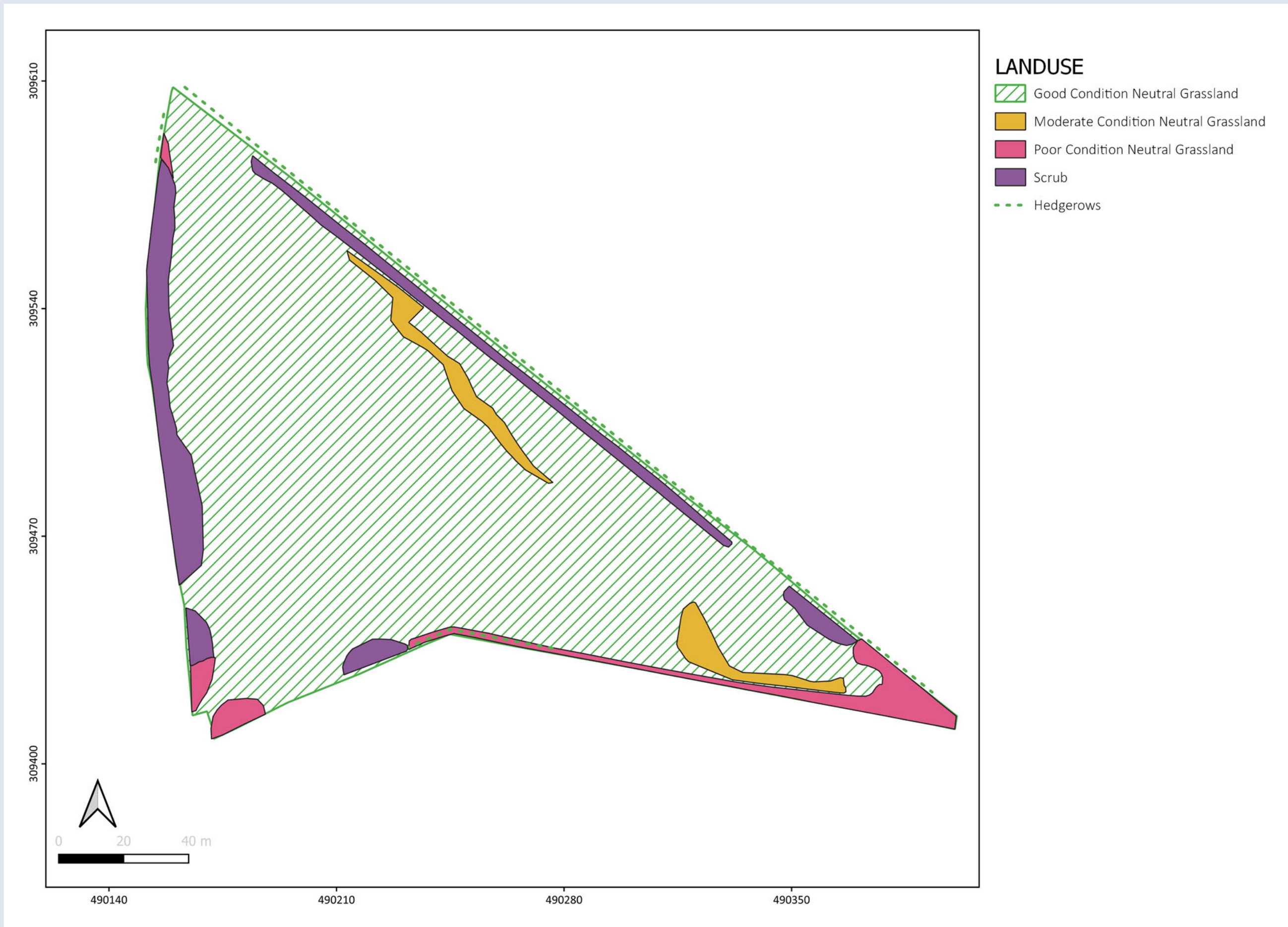

FIGURE 1 Map of predevelopment land use at Dickenson's Field

for the natural environment" (Rutland County Council, 2011, p. 55).

Local regulations encourage enhancements in hedging and provisions for several protected species such as barn owls (*Tito alba*). This approach is consistent with both the aims of improving conditions for biodiversity and giving priority to local aims and targets. However, these two aims conflict where local policy is enforced to prevent conversion of locally prioritized neutral grassland to other habitat types. The

TABLE 2 Area of different habitat types at Dickenson's Field

Area of Defra Metric 3.0 habitat types	Predevelopment baseline (ha)	Postdevelopment scenario (ha)
Good condition neutral grassland	1.82	1.38
Moderate condition neutral grassland	0.07	
Poor condition neutral grassland	0.09	
Scrub	0.18	0.18
Broadleaved woodland		0.1
Traditional orchard		0.2
Pond		0.04
Built environment		0.26
Green roof		0.07
Hedgerow (length in meters)	350	370

Note: Pre- and postdevelopment values are not equal because the green roof is constructed on top of the built environment.

TABLE 3 Comparison of normalized ecosystem service (ES) provision change scores from RAWES+, the EBN Tool, and NATURE Tool across shared ES categories at Dickenson's Field

Neutral and/or minor change (0)			(−0.25 to 0.25 points out of 10)		
Increase (+)			(0.25–2.5 points out of 10)		
Large increase (++)			(more than 2.5 points out of 10)		
Decrease (−)			(−0.25 to −2.5 points out of 10)		
Large decrease (−−)			(more than −2.5 points out of 10)		
Not applicable and/or not assessed (blank)			Service not assessed		
RAWES+	EBN Tool	Nature Tool	RAWES+	EBN Tool	NATURE
Ecosystem services				30 years	
Food production	Food production	Food and fish—commercial	+	−	0
	Fish production	Food and fish—community		0	+
Fresh water	Water supply	Water availability	+	−	−
Fibre and fuel production	Wood production	Wood production	0	+	0
Biochemicals, natural medicines, pharmaceuticals			0		
Genetic resources			+		
Ornamental resources			0		
Clay/minerals/aggregates			0		
Waste disposal			0		
Energy harvesting		Photovoltaic carbon impact	++		+[a]
Global climate regulation	Carbon storage	Carbon storage	0	−	0
Pollination	Pollination	Pollination	++	−	−
Water regulation	Flood regulation	Flood regulation	0	0	0
Water purification and waste treatment	Water quality regulation	Water quality regulation	+	−	0
Air quality regulation	Air quality regulation	Air quality regulation	0	0	0
Erosion regulation	Erosion protection	Erosion protection	+	−	−
Local climate regulation	Cooling and shading	Cooling and shading	+	0	0
Pest regulation	Pest control	Pest control	+	−	−
Natural hazard regulation			0		
Disease regulation—human			0		
Disease regulation—stock			0		
Noise and visual buffering	Noise reduction		+	0	
Salinity regulation			0		
Fire regulation			0		
Aesthetic values	Aesthetic value	Aesthetic values	+	+	−
Education and research	Education	Education and knowledge	++	++	++
Recreation and tourism	Recreation	Recreation	0	+	−
	Sense of place	Sense of place		0	−
Cultural heritage			++		
Spiritual and religious value			0		

(*Continued*)

TABLE 3 (*Continued*)

RAWES+	EBN Tool	Nature Tool	RAWES+	EBN Tool	NATURE
Inspiration			0		
	Interaction with nature	Interaction with nature		+	−
Social relations			+		
Nature targets			+		
Soil formation			0		
Nutrient cycling			0		
Primary production			++		
Water recycling			0		
Photosynthesis (atmospheric O_2)			0		
Provision of habitat			++		

[a]Abbreviations: EBN Tool, the Environmental Benefits from Nature Tool; NATURE Tool, Nature Assessment Tool for Urban and Rural Environments; RAWES+, Rapid Assessment of Wetland Ecosystem Services+.
[a]Estimated value.

county-level policy preventing conversion of neutral grassland conflicts with advice from Natural England to improve biodiversity on a wider scale (through increased buffering of the neighboring SSSI and increased habitat heterogeneity providing greater benefits to fauna throughout the year).

The open-ended and subjective nature of these policies makes it difficult to conclude whether their application can consistently achieve its aims of maintaining and improving biodiversity. However, it does seem an effective way of clearly articulating and prioritizing local aims and targets.

Biodiversity Net Gain (BNG). The wider aim of BNG, as expressed in Defra's consultation on mandatory net gain (Department of Environment, Food and Rural Affairs, 2018, p. 9), was that "Mandating biodiversity net gain could ensure that new development enhances the environment, contributes to our ecological networks, and conserves our precious landscapes."

Enhancing the environment can be seen as going beyond just enhancing biodiversity. For example, the Department of Environment, Food and Rural Affairs (2018, p. 16, Figure 2) describes "Environmental net gain" as including a mix of biodiversity, ESs, and natural capital pressures. Biodiversity is critical to the functioning of ecosystems and the services they provide (IPBES, 2019; Seddon et al., 2021), simplistically implying that Department of Environment, Food and Rural Affairs (2018) BNG should result in wider ES net gain, although in reality the association between biodiversity and ESs are multilayered and cannot be automatically assumed (Mace et al., 2011). As such, whether the Defra Metric's outputs can be seen to "enhance the environment" will be tested by whether it can be seen to have enhanced both biodiversity and ESs.

Without extensive field surveying of the site once the development has been completed, it is hard to prove empirically whether the Defra Metric's position on the plan is correct or not, although its divergence from Natural England recommendations (see Supporting Information: Section 1b) suggest that it does not reflect likely benefits. Furthermore, the results of this study (see Supporting Information: Section 1b) indicate that the tool is unable to consider either scale or heterogeneity of habitat, both of which are crucial for biodiversity (Báldi, 2008; Benton et al., 2003), ecosystem functioning and/or services, and resilience (Bullock et al., 2022; Pendleton et al., 2020; Waters, 2022).

Although BNG takes some account of connectivity (in particular where offsetting is conducted off-site and in connection to the local priority area), it fails in its aspiration to contribute to ecological networks in the Dickenson's Field case study by failing to assimilate local context-specific data from outside the redline boundary of the site. This led to the tool showing a net reduction in habitat units in a scenario specifically requested in Natural England advice to the applicant to improve the connectivity and buffering of an important local wildlife site, Burley and Rushpit Woods SSSI, on a landscape scale, by incorporating more scrub and increasing the structural complexity of the site's western boundary, to "complement the adjacent SSSI, by providing a more complex and stable vegetation structure for year-round benefit to a wider range of fauna." Natural England also suggested that "Incorporation of small pond/s would also aid complementary benefit and provide additional educational value," small pond creation also decrementing BNG score by conversion of grassland. Although only a very limited change in the scrub border and a single pond were planned at Dickenson's Field, as shown (see Supporting Information: Section 7), any change of baseline habitat, including the addition of scrub and/or ponds as suggested by Natural England, leads to a reduction in habitat units in the Defra 3.0 Metric.

With no objective definition of precious landscapes, it is difficult to conclude whether the Defra Metric helps conserve precious landscapes. However, if the Defra Metric's fifth principle (in Panks et al., 2021), that the tool is designed to discourage change in habitat type, is taken as an aim to

FIGURE 2 Map of postdevelopment land use at Dickenson's Field

conserve "precious" landscapes, then the tool does complete this aim in the tested scenario by punishing any change to "good condition other neutral grassland" (listed as important in local legislation).

The Environmental Benefits from Nature Tool (EBN Tool). The EBN Tool was designed to "indicate how changes to habitats can affect the services provided by nature and the benefits to people" (Smith et al., 2021a). The EBN Tool aims to achieve this through three design principles:

(1) "Simple and easy to use, using freely available data and/or data gathered as part of Phase 1 or equivalent surveys." The first design principle hasn't been assessed directly in this analysis because it relates to the application rather than the scope or results of the tool.
(2) "As scientifically robust as possible, using best available evidence." The EBN Tool fails this design principle for two reasons:

First, it has little flexibility in the data it can assimilate, leading, on several occasions, to the EBN Tool showing decreased ES, then suggesting actions that were already included in the assessed postdevelopment plan to remedy the loss. For example, for "Pollination" and "Pest control" services, the EBN Tool "Interpretation" advises increasing plant diversity and structural diversity of the habitat, adding green roofs, shrubs, hedges, and trees, and leaving grass to grow long before mowing. All these suggestions were already included in the assessed postdevelopment plan. Similarly, the assessment of the reduced "Food production" service triggered the EBN Tool advice to "Consider inclusion of allotments or community orchards if appropriate," failing to account for the fact that a community orchard was already part of the assessed development plan (and would also involve converting preexisting habitat with its associated services).

Second, each habitat type is accorded a baseline score for each ES. Although the systematic literature review that informed many of the baseline scores (Smith et al., 2017) is publicly accessible and peer-reviewed, the way in which this was combined with existing tool scores and expert consultations is opaque. As such, it is difficult to independently verify the baseline scores given to each habitat type for each ES. This is especially relevant because the baseline scores for some services assessed by both the EBN Tool and NATURE Tool differ between the two methodologies. For example, the NATURE Tool gives bracken a 6 out of 10 for "Education" and the EBN Tool gives bracken a 4 out of 10.

Third, according to Smith et al. (2021b): "Able to incorporate the impact of ecosystem condition and quality and spatial location on ecosystem service (ES) supply." The EBN Tool uses an extensive range of indicators to determine the condition of different habitat types, including "ground cover %," "shrub layer," and "invertebrate nesting sites" (Smith et al., 2021b). Furthermore, the tool accounts for several habitats only providing certain services in specific spatial locations. For example, a hedge is only useful for "Noise regulation" if it is between a source of noise and a potential sink. However, like BNG, the EBN Tool does not operate across wider spatial scales than the site (and any offsetting area). Therefore, as acknowledged by Smith et al. (2021c), it does not account for trade-offs in ES use (by either communities or species) when a habitat is lost on-site and compensated at a different location.

Nature Assessment Tool for Urban and Rural Environments (NATURE Tool). The NATURE Tool was designed as "a mechanism to assess both a site[']s" baseline natural capital and changes to it through development (Nature Tool, n.d.). It aims to achieve this through "transparent and objective assessments against clearly defined objectives" (Hölzinger et al., 2022), including the ability to assess against local or project-specific priorities. The NATURE Tool's authors acknowledge the inherent difficulties entailed in creating a fully accurate ES tool in a complex system with missing data, so instead aim to "offer a user-friendly experience that generates better outcomes compared to the status quo where natural capital performance and impacts are often undervalued or ignored" (Hölzinger et al., 2021).

This aim includes three factors:

(1) Baseline natural capital and changes. The NATURE Tool aims to measure changes in "natural capital performance." However, it is unclear in practice if the tool is measuring baseline natural capital, that is, the ability of an area to provide ES, or benefits to people actually realized. For example, both the "Esthetic values" and "Interaction with nature" services in the NATURE Tool receive a baseline score even if there is no public access to the site and therefore the services cannot be used. This would be consistent with a tool measuring natural capital rather than ESs, because ESs are only ESs if clearly linked to beneficiaries (Everard, 2022; McVittie & Faccioli, 2020) and therefore would have no baseline score if not used. However, the scores for both services increase if you increase public access to the site, even if the baseline land cover has not changed. This seems to imply that the tool is measuring ESs, as natural capital does not change with use. As such, in this case study, the tool seems to neither be strictly measuring natural capital nor ESs.

(2) Transparent and objective, clearly defined objectives, and local or project-specific priorities. The NATURE Tool allows individuals, developers, and statutory bodies to input their own objectives and priorities to the assessment. For example, a user could input a minimum change score for a service category, state the "priority" level of a service, or decide whether a service is mandatory or to be removed from the assessment entirely. However, this ability for a developer to write project-specific objectives, in particular the ability to remove certain services from assessment, could open the assessment to bias and siloed thinking. Within the tool, aggregate scores are calculated by multiplying the average score for each service by an aggregation weighting dependent on its policy priority. In practice, however, this can allow an improvement to a high-priority service in policy to obscure a loss to one or more low-priority services in the aggregate score (Everard, 2022, p. 78). For example, in the case study, inbuilt policy priorities for England were used, with "Air quality regulation" given high priority and a 19% score aggregation for the "Regulating and supporting" aggregated score, whereas "Water quality regulation" was given a low priority and a 6% weighting. With these policy priorities, a 10% increase in "Air quality regulation" would outweigh a 30% decrease in "Water quality regulation" in the aggregated score. Although the unit scores and change scores for each individual service are shown in the tool's results, the aggregate scores could lead to further siloed decision-making.

Although many of the calculations in the NATURE Tool are accessible to the user both through the tool and the user guides (Hölzinger et al., 2022), as with the EBN Tool there is no transparency in the origin of the baseline ES scores for each habitat. This could reduce faith in the outcomes especially, as previously stated, when these baseline scores conflict with other tools.

(3) Better outcomes than the status quo. Despite these problems, the NATURE Tool undoubtedly has benefits over the current status quo of a patchwork of local policy and BNG (noting that the NATURE Tool largely uses the Defra Metric in its assessment of biodiversity). The tool takes a more holistic approach to measure a large and consistent range of "natural capital benefits." This reduces the likelihood of natural capital performance and impacts being undervalued or ignored and can help inform both assessors and developers about the multiplicity of relationships between on-site natural capital and the built environment. However, despite this more holistic approach to built environment–ecosystem interactions, the NATURE Tool could still lead to worse outcomes than local policy because it does not consider habitat heterogeneity or the wider spatial scales on which biodiverse ecosystems (and many ESs) depend.

Rapid Assessment of Wetland Ecosystem Services+ (RAWES+). The RAWES+ approach follows the same principles and aims as the RAWES approach, but has been modified for measuring the change in ES provision over a regime change, such as that caused by development of a site (Cianchi et al., 2023). RAWES has been designed to provide a qualitative assessment of a "comprehensive range of wetland ecosystem services" (RRC-EA, 2020) on a systemic basis

(McInnes & Everard, 2017). Although specifically developed for wetland assessment, RAWES is adapted from an approach applied to a range of habitat types and can be used across a range of scales from whole landscapes to localized zones of large and complex ecosystems (McInnes & Everard, 2017). RAWES assessments are furthermore designed to be rapid and cost-effective, an aim relating to application of the tool and not what it measures (for this reason, rapidity is not evaluated in this study).

(1) RAWES+ spans a comprehensive range of services assessed over a range of spatial scales. evaluating a minimum of 36 different ESs from across the four Millennium Assessment (Millennium Ecosystem Assessment, 2005) categories (provisioning, regulating, cultural, and supporting; RRC-EA, 2020). In addition, the methodology allows the inclusion of further local or contextually relevant services to the assessment. For example, an additional cultural service of "Nature targets" was added to the assessment of Dickenson's Field (see Supporting Information: Section 2), to recognize the service the site provides through supporting species or habitats that have been deemed important in legislation or targets such as national priority habitats. The supporting role the site plays to the adjacent Burley and Rushpit Woods SSSI was used as evidence for this service on a "local" scale. As RAWES assessments are done on the basis not only of a standard set of 36 ESs but augmented by additional, contextually relevant services, results from different RAWES+ assessments cannot be compared automatically because each site may have its own contextually relevant baseline.
    Unlike BNG, the EBN Tool, and the NATURE Tool, RAWES+ assesses ES benefits across each of multiple spatial scales defined at the set-up phase by assessors (Cianchi et al., 2023). RAWES+ assessment of the Dickinson's Field site used four spatial scales: site, local, national, and global. Although no services were scored negatively at one scale and positively at another in the case study, the use of multiple spatial scales allowed the assessment of benefits realized off-site (such as at Burley and Rushpit Woods SSSI or global contribution to climate regulation) and can reveal when service provision is increased by widening its spatial scale of benefit, rather than just increased benefit on-site. As RAWES+ allows different spatial scales to be used for different assessments, this can reduce comparability between sites.
(2) Assessment on a systemic basis. There are multiple definitions of the word "systemic" and much overlap in the literature between the terms systemic and systems thinking. For clarity, in this study a systemic assessment is taken to mean an assessment conducted using a systems thinking approach.

Cabrera et al. (2008) and Arnold and Wade (2015) describe some of the many conflicting and concordant definitions and models of systems thinking. However, this study was tested against Donnadieu et al.'s (2003) four basic concepts of the systemic approach—the complexity, the wholeness, the interaction, and the system—acknowledging Nguyen and Bosch's (2013) definition of systems thinking as focusing on "the whole system as well as the constituent parts and their interactions." Taking Nguyen and Bosch's (2013) definition in conjunction with Arnold and Wade's (2015) argument that systems thinking is a system in itself, we should expect blurred boundaries between Donnadieu et al.'s (2003) basic concepts and therefore expect the testing of RAWES+ against one concept to produce insight into its performance against the others.

- The complexity: Donnadieu et al. (2003, p. 3) define the concept of complexity as "difficulties of comprehension (vagueness, uncertainty, unpredictability, ambiguity, randomness) posed by the apprehension of a complex reality and which is perceived by the observer as a lack of information (available or not)." RAWES+ can be seen as trying to address this complexity by synthesizing qualitative in addition to quantitative data, allowing multiple value types to shape decision-making and allowing an assessment of the system without perfectly understanding every cog. This is in alignment with Donnadieu et al.'s (2003, p. 4) argument that "the nature and the type of interaction is more important in the systemic approach than to know the nature of each component of the system."
- The system: The broad definition of the system given by Donnadieu et al. (2003) is that a system is a set of dynamically interacting elements. RAWES+ addresses this concept by operating across the full suite of ESs and across all spatial scales (as discussed above), acknowledging the earth as a whole rather than the site as the boundary of the socioecological system. This is further addressed in the concepts of wholeness and interaction below. Furthermore, as services are assessed in the context of each other, interactions including potential feedback loops and trade-offs should be identified. However, the RAWES+ system at present does not address all temporal aspects of the system, instead providing snapshots before and after the development process. Furthermore, RAWES+ does not address elements of the socioecological system that are not directly mediated by the environment, such as trade-offs between social and economic elements of a development.
- Wholeness: Operationally, wholeness is the conceptual opposite to siloed thinking, in which the full system is greater than the sum of its parts, and parts cannot be truly understood except in the context of the system (Donnadieu et al., 2003). It is heavily linked with the concept of interaction, in that it addresses the interdependence of elements of the system.
- Interaction: Interaction furthers the concept of wholeness by focusing on the links and interdependencies between

elements of the system (Donnadieu et al., 2003). RAWES+ addresses these concepts by assessing all potential ESs, including supporting services, rather than taking a siloed approach. Many economically focused approaches to ESs (such as TEEB [Kumar, 2011] and the UK NEA [2011]) fail to include supporting services in their calculations, as a "protection" against double accounting, instead valuing ESs purely at the point of use (Everard, 2022). The justification for this omission is that supporting services (and some of the regulating services) are "intermediate services" that facilitate production of other, more directly consumed services, and so their value is included when the other service categories are accounted for (at the point of use; Everard, 2022). However, because supporting services are essential to the "production of all other ecosystem services" (RRC-EA, 2020), it is dangerous to omit current and future functioning and the resilience of the supporting system from decision-making. Moreover, assessment of supporting services can be seen as furthering understanding of interactions between elements of the system as they act as links between multiple different directly consumed ESs.

DISCUSSION

None of the assessed tools and/or approaches applied fully met their stated aims and/or objectives. Many of the reasons for the tools' inability to meet their objectives, and for the divergence among the results of the five approaches, related to the methodological standpoints on which they were framed. This ability of tools to meet their stated aims has implications for their ability to assess regenerative development. Application of these tools and/or approaches to the Dickenson's Field case study highlighted four primary, interlinked themes shaping their results: type and breadth of data assimilated; acuity of derived scores; indicator type measured (biodiversity, natural capital, or ESs); and siloed, fragmented, or systemic framing.

Type and breadth of data assimilated

Whether a tool uses quantitative or qualitative data had a major impact on its ability to meet its objectives, in large part through data gaps, and also whether it was able to assimilate data across scales and contexts. This has particular relevance to assessing within the regenerative themes "importance of place" and "systems thinking." As the systems of biodiversity present on-site and across landscapes are extremely complicated and, in many cases locally specific, to accurately represent these systems any quantitative model would require an extraordinary number of data fields and a full understanding of the myriad interactions and interdependencies among them. As this is completely impractical for both temporal and financial reasons, BNG, the EBN Tool, and the NATURE Tool all use broad habitat types as proxies. This simplification of the system reduces the ability of the user to input context-specific information, borne out in three principal ways across the tools.

- First, the lack of ability for BNG to consider what is going on outside the redline boundary means it conflicts directly with expert advice from Natural England.
- Second, the EBN Tool advises the applicant to improve their scores by taking actions already planned, some of which the applicant is unable to input into the tool.
- Third, none of the quantitative tools considered spatial scale and (with the exception of some references in the EBN Tool to structural diversity, and the inclusion of the number of habitats when calculating aesthetic value) habitat heterogeneity despite their importance for both biodiversity and ES provision.

Although this use of a limited number of categories in which to frame a site made the tools quick and easily applicable, it rendered them unable to adapt to local context. This is not to say that using qualitative data is in itself a solution or that it does not introduce associated challenges. Incorporation of qualitative aims and data allows LNRPP to act flexibly. However, it also makes it very difficult to determine if goals have been definitively attained. This uncertainty has potential implications for the "adding positive value" regenerative theme. This ambiguity of result can lead to disagreements between stakeholders about the value of a proposal (Tainter, 2012) and is potentially open to bias.

Acuity of derived scores

Broad categorization of outputs of some tools and/or approaches may hide nuances of change, with implications for assessing the theme of "adding positive value." For example, because RAWES+ uses broad categories of service provision (positive or significantly positive or negative), assessments may not always recognize a small increase or decrease in service provision. For example, the Dickenson's Field site predevelopment would be assessed as positive at a local scale for "Fibre and fuel production" as it produces hay used by a local farmer and would still do so post-development albeit from a smaller area of land delivering less product. Despite this decrease in product, the site would still be providing a positive service at the local scale, and therefore the score for "Fibre and fuel production" would not change. Furthermore, the flexibility and context-specificity allowed in RAWES+ assessments mean that outputs cannot automatically be compared between sites unless a baseline suite of services relevant to the compared sites is first agreed when determining the purpose of the assessment. Without such agreement, RAWES outputs may be less readily replicated than quantitative, reductive counterparts.

Indicator type measured

The indicator type used for measuring sustainability and/or net gain had a noticeable impact on the tools' results, in large part by affecting their ability to assess single issues or to do so more systemically. This has implications not only for the "systems thinking" regenerative theme but also, in the case of these tools, their ability to measure the addition of positive value and to incorporate the importance of place.

As shown in the Results section, addressing biodiversity alone through the Defra Metric (3.0) does not lead to wider ES or environmental net gains. This is largely through a failure to acknowledge the wider system of interactions between the built environment and ecosystems. Practically speaking, even where the emphasis is just on nature, this siloed approach can cause problems. For example, Potschin et al. (2016) argue that the wider values of nature are undervalued when viewed through a narrow lens of nature conservation priorities in isolation.

The EBN Tool, NATURE Tool, and RAWES+ all use broader indicator types in either natural capital or ESs. RAWES+ assesses ES, whereas the NATURE Tool and the EBN Tool assess a mix of natural capital and ES. Although similar, the link to beneficiaries inherent in ESs (Small et al., 2017) contrasts with the pure potential to supply services measured by natural capital. The choice of which of these indicators to use is not trivial, as the use of one approach or another could change which site is chosen, or what interventions are selected in a development context. For example, in a utilitarian sense, a site could be chosen because it has the highest natural capital but, if there are no beneficiaries for the natural capital to support, it may make more sense to channel investment to a site with higher ES so the same financial capital can benefit more people.

Conversely, the direct link to beneficiaries could cause problems in application of RAWES+. For example, the value of ESs could be enhanced by increasing the number of beneficiaries. McVittie and Faccioli (2020) touch on this problem in a case study in Clackmannanshire, arguing that several assessed services (such as "Recreation and flood protection") can increase in importance post-development owing to the increased population and demand on-site.

Siloed, fragmented, or systemic framing

The siloed, systemic, or fragmented framing of an approach is important not only for addressing the regenerative theme of "systems thinking," but also affects the ability of tools to address all three other regenerative themes. Both LNRPP and BNG operate from siloed positions focusing purely on biodiversity, which does not automatically lead to greater environmental benefits. Furthermore, narrow focus on single issues or services can disconnect findings from the systematic nature of both problems and their potential solutions (Bradshaw et al., 2021) and can impart high costs on overlooked parts of the system or constituencies of people (Everard & McInnes, 2013).

The EBN Tool and the NATURE Tool take a more holistic approach than BNG or LNRPP, but still fail to consider the whole system by not synthesizing data across multiple scales or considering supporting ESs. Considering spatial scales is particularly crucial, because trade-offs in the use of ecosystems can often occur across services, scales, or constituencies (Everard, 2020; Small et al., 2017). Furthermore, the NATURE Tool allows weighting by policy priorities and, therefore, differential valuation of each ES in aggregated scores. This is nonsystemic in two ways. First, all elements of the socioecological system are interdependent, albeit often in ways that are currently poorly understood, so emphasizing the importance of one element over others affects functioning of the system as a whole with the potential for unintended consequences (Bradshaw et al., 2021). Second, today's developer cannot know the value systems of all the different stakeholder groups benefiting from the site at present nor the policy priorities of tomorrow. Therefore, emphasizing current politically prioritized elements of the system to the detriment of others may rob less influential constituencies and future generations of the services they may deem important, potentially undermining the unambiguous commitment to intergenerational equity in the "Brundtland" definition of sustainable development (WCED, 1987).

The type, and importantly breadth, of data used (including the ability of tools and/or approaches to synthesize multiple scales and local context) largely determines the ability of an approach to examine beyond a single, or fragmented group of issues, to the whole system.

Although taking a quantitative approach all but precludes systemic assessment, it does not necessarily follow that using a qualitative approach makes an assessment systemic. Local planning policy is often a patchwork of policies focused on specific siloed areas of concern. As such, areas of importance can be missed, and contradictory policies implemented. RAWES+ attempts to assess services provided by sites systemically by addressing a full range of ESs across multiple spatial scales but ultimately, for the sake of practicality including its objectives of rapid and readily delivered assessment, is subject to questions about the boundaries of the system (Berardi, 2015; Clegg, 2012).

Thinking about complex socioecological systems systemically is essential to the transition to regenerative development (Camrass, 2021; Cole, 2012; du Plessis & Brandon, 2015; Gibbons et al., 2018; Reed, 2007). Most of the problems the selected tools and/or approaches have with meeting their stated objectives (identified through application) are based on their differential inability to act systemically. For most tools, this is linked to their quantitative methodologies, which in a complex, changing system require inherent reductionism. Local policy makes it clear that taking a flexible qualitative approach does not provide a systemic assessment of itself and can lead to subjective and ambiguous measures of success.

CONCLUSION

Camrass (2021) identifies a lack of understanding of the differences between the underlying philosophical positions of current planning and evaluation frameworks, as compared with those necessary for regenerative development, as one of the key challenges to the operationalization of the regenerative approach. This study takes a novel approach to address this research gap through the comparison of current approaches, and how they meet their stated and wider regenerative aims, by considering their application on a case study site.

The results of this study demonstrate that the methodological foundation on which built environment sustainability tools or approaches is based affects the outcome of its application. This has implications both for the use of currently available approaches to encourage and assess a shift in development to a new regenerative paradigm, and for the development of novel tools. All the approaches tested addressed the "importance of place" and "adding positive value" themes of regenerative thinking, whereas RAWES+ also attempted to take a "systems thinking/living systems" approach. However, none of the approaches tested attempted to address the fourth regenerative principle "Co-evolution between sociocultural and ecological systems." The principle of co-evolution takes us far beyond the time frame relevant to the planning and construction of built development and into an ongoing process in which living in the development within its specific socioecological context generates further positive environmental and social outcomes (Cole et al., 2013; Mang & Reed, 2012). Addressing this principle in future tools poses further questions of our broader place within socioecological systems, the types of value we assess, and the need to transition from product-focused to process-focused tools and approaches.

Although BNG, the EBN Tool, and the NATURE Tool have specific problems, they all share some common difficulties inherent in the mechanistic methodological approach and reductive paradigm which make it difficult to achieve their own goals, let alone wider regenerative aspirations. The regenerative position advocated in the literature is systemic and collaborative in nature, also emphasizing local context, and therefore cannot be approached using a quantitative tool that forces reductionism (Mang & Reed, 2012). Instead, the complexity inherent within the concept of socio-ecological systems must be addressed systemically through the new ecological worldview. The qualitative approach taken by RAWES+ and LNRPP can facilitate a greater understanding of "place" than reductive approaches, integrating a wider suite of value systems, and can also be used systemically. However, the value a reductive tool provides for comparison between sites, unambiguity, and replicability is clear, and achieving this utility is a clear challenge for tool development in the new regenerative paradigm (Tainter, 2012).

AUTHOR CONTRIBUTION

Ben Cianchi: Conceptualization; data curation; formal analysis; investigation; methodology; visualization; writing—original draft preparation; writing—review and editing. **Mark Everard**: Funding acquisition; methodology; project administration; supervision; validation; writing—review and editing. **Bill Gething**: Supervision; writing—review and editing. **Rob Cooke**: Funding acquisition; supervision; writing—review and editing. **Martino Ginepro**: Resources.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data and associated metadata and calculation tools for this research are available, upon request, from corresponding author Benjamin Cianchi (ben.cianchi@uwe.ac.uk).

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SUPPORTING INFORMATION

Section 1. Detailed results of the application of each approach to the case study.

Section 2. Description of the 'Nature targets' ecosystem service.

Section 3. Defra Metric 3.0 completed for the case study site.

Section 4. The EBN Tool completed for the case study site.

Section 5. The NATURE Tool completed for the case study site.

Section 6. RAWES+ completed for the case study site.

Section 7. Results of theoretical tests within the Defra Metric 3.0 whereby a homogenous baseline was changed within the metric to every available habitat type and across different scales.

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