Environmental Science and Policy 120 (2021) 73–80

Contents lists available at ScienceDirect

Environmental Science and Policy

journal homepage: www.elsevier.com/locate/envsci

Review

Are field boundary hedgerows the earliest example of a nature-based solution?

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ARTICLE INFO

Keywords:
Hedgerow
Nature-based solutions
Co-benefits
Field boundaries

ABSTRACT

The arrival of the phrase *nature-based solutions* into the lexicon of academics, planners, managers and policy makers in recent years has sparked a heated debate as to the effectiveness of using nature as a viable solution for mitigating the impacts of anthropogenic environmental change. One of the difficulties of evaluating the potential efficacy and impact of nature-based solutions is that it is believed that there is little evidence by way of a precedent or long-term successful examples. Much literature exists on the subject of designing with nature to provide multi-functional green infrastructure, connectivity in the landscape, and ecosystem service provision. Indeed, in the opinion of many, the nature-based solution approach appears to synergise research into green infrastructure, ecological connectivity and ecosystem service provision for building climate-related resilience. However, when a nature-based solution has been specifically selected over, say, an engineered solution the literature is rather less clear. So, decision-makers may find it necessary to rely on less reliable sources of impact evidence. This paper argues that field boundary hedgerows may be considered to be exemplars of a nature-based solution, one that was planned, designed, perfected and mainstreamed at a landscape scale, that was specifically selected over a non-nature-based solution, and one that is still in providing solutions and co-benefits today. Therefore, hedgerows may provide some perspective into the potential or emergent co-benefits that the current nature-based solution approach seeks to provide.

1. Introduction

In the last 10 years the term *nature-based solutions* has gradually entered into policy and scientific discourses with a view to innovating with nature to address biodiversity and climate-related issues (Eggermont et al., 2015) among other global societal challenges. The phrase (often conflated to NBS) has emerged as a potential panacea for tackling the detrimental effects of human progress in cities using co-creation processes (van der Jagt et al., 2018). There are numerous working examples globally of nature-based solutions in action[1], and the phrase was originally devised for advocating the large-scale management and restoration of ecosystems in order to achieve multiple co-benefits especially for biodiversity and human livelihoods (Monty et al., 2017).) Nature-based solutions were original mooted as an umbrella term encompassing various ecosystem-based approaches such as ecosystem-based adaptation or forest landscape restoration (Cohen--Shacham et al., 2016). While the term *nature-based solution* is a novel conceptualisation within the growing lexicon of sustainability science, it is by no means a new concept. At its broadest conceptualisation, exploited nature has always provided the wherewithal (or 'solution') for human survival and societal progress. Greatly enabling the growth and prosperity of civilisations and thus the development of modern society.

Another nature-based solution approach sees nature as a resource which can be used to mitigate the negative effects of climate change (Calliari et al., 2019), build cohesion (Frantzeskaki, 2019), social-ecological resilience (Collier et al., 2013), and thus provide co-benefits over time (EC, 2015). With the growing focus on regreening cities, nature-based solutions have been championed as the panacea (Frantzeskaki et al., 2019). There is a growing desire to scale them out across all cityscapes in multiple formats such as living roofs, living walls (interior as well as exterior), bioswales, and so on, and there is a high potential for financing such a movement (EIB, 2018) and has seen the emergence of the move towards a nature-based economy (e.g. the EU Green Deal). As an effective competitor for an engineered solution these nature-based solutions are still in their relative infancy and current research is mainly focussed on deriving indicators for evaluating their efficacy. The underlying goal of innovating with nature-based solutions is to foster mechanisms for inclusive and collaborative approaches to

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[1] See: https://www.iucn.org/theme/nature-based-solutions

https://doi.org/10.1016/j.envsci.2021.02.008
Received 10 April 2020; Received in revised form 29 January 2021; Accepted 12 February 2021

re-greening cities (Frantzeskaki et al., 2020). Thus, nature-based solutions are considered to be promising vectors to co-create and co-design future, climate-resilient communities and address the multiple social and cultural pressures that increased urbanisation, for example, brings with it (Albert et al., 2019; Bourguignon, 2017; Frantzeskaki, 2019; Robinson and Breed, 2019).

It is arguable that engineered solutions to tackle societal problems will leave nature a distant second in the market for providing innovative, viable and effective solutions. However, one of the advantages of the nature-based solution approach is that, almost by definition, a nature-based solution should *appreciate* in value (e.g. biodiversity and ecosystem service provision) over time and therefore provide additional and potentially unexpected co-benefits (EC, 2015). This is unlike most engineered solutions which tend to *depreciate* in value over time, often require upgrading and providing few, if any, co-benefits (e.g. cultural ecosystem services). In many instances it is tempting to *rebrand* existing green infrastructure (parks, street trees, forests, etc.) as legacy nature-based solutions because they provide unplanned co-benefits, especially in, for example, urban areas (EC, 2015; Frantzeskaki, 2019; Hernández-Morcillo et al., 2018; Raymond et al., 2017a, 2017b; Robinson and Breed, 2019). This perspective paper takes as a starting point the view that one of the first truly deliberate, scalable and continually effective nature-based solutions in the modern era are field boundary hedgerows.

Hedgerows are living, linear field boundaries that are designed to enclose (or exclude) livestock, often consisting of thorny tree and shrub species set in a linear, inter-connecting configuration. They also delimit property and jurisdictional boundaries. Once a common feature of northwestern European landscapes, many hedgerows have been extensively removed since the 1950′s, and in many cases, they have been replaced with more engineered solutions such as barbed wire or electric fences. Yet, hedgerows are still pervasive in many European landscapes (Dover, 2019; Müller, 2013) though they can also be found in North America, Kenya, India, and other countries that were colonised by European countries (Fritz and Merriam, 1993; Iversen, 1981; Moxham, 2001; Mwangi et al., 2012). Where extant, hedgerows are often still providing those solutions for which they were created (enclosure, delineation, animal shelter, etc.) and, as this paper will argue, over time they have attained unforeseen co-benefits. Thus, given the perspective of time along with geopolitical and environmental change, hedgerows could be considered to be prototypical nature-based solutions. The paper provides some of the key attributes of the co-benefits of a nature-based solution, based on those emerging from reviewing the field boundary literature, with a view to guiding the scaling out of nature-based solutions.

2. Nature-based solutions

Definitions of nature-based solutions abound, and the search for a practicable definition is ongoing (Eggermont et al., 2015). The earliest IUCN definition sees nature-based solutions as “actions to protect, sustainably manage and restore natural or modified ecosystems, which address societal challenges (e.g. climate change, food and water security or natural disasters) effectively and adaptively, while simultaneously providing human well-being and biodiversity benefits” (Cohen-Shacham et al., 2016; p. 2). The European Commission focusses more on the multiple co-benefits of nature-based solutions which: “harness the power and sophistication of nature to turn environmental, social and economic challenges into innovation opportunities. They can address a variety of societal challenges in sustainable ways, with the potential to contribute to green growth, ’future-proofing’ society, fostering citizen well-being, providing business opportunities and positioning Europe as a leader in world markets” (EC, 2015). More succinctly, nature-based solutions are: “actions which are inspired by, supported by or copied from nature” which result in “multiple co-benefits for health, the economy, society and the environment, and thus they can represent more efficient and cost-effective solutions than more traditional approaches” (EC, 2015). In addition, the EC has sharpened its definition by insisting that if it does not boost or support biodiversity and ecosystem service provision, it cannot be labelled a nature-based solution. Eggermont et al. (2015) conceptualise three types of nature-based solutions: type 1: those that follow the IUCN approach and see them as mechanisms for managing and restoring protected ecosystems; type 2: those that fit the broad theme of the agri-environment for augmenting the sustainability and multifunctionality of managed landscapes; type 3: those that follow the EC definition and seek to (re)create ecosystems in heavily impacted areas, such as cities. Cohen-Shacham et al. (2019) illustrate how this approach can be refined with a view to a common approach to nature-based solutions being adopted under the proposed IUCN ‘Global Standards for Nature-based Solutions’[2] . However, while these Standards do not provide an (as yet) agreed upon definition suited to all practitioners and policymakers, it is clear that a nature-based solution is not just passive green infrastructure (e.g. street trees or a park) or the result of a valuing of newly recognised ecosystem services. A nature-based solution is specifically designed, or preferably co-designed, to address multiple, interconnected problems (ecological, environmental, social, etc.), in a manner that has multiple co-benefits (also ecological, environmental and social, etc.).

Therefore, it is clear that in order for nature-based solutions to be scalable and effective it is essential, from the outset, to have identified a specific problem or problems whose solution is best provided by living structures. Thus, it follows that the solution in question ought to be competitive with non-nature-based solutions that are deployed to address the same initial problem in terms of impact, cost-effectiveness and additional benefits. In drawing lessons from a specific nature-based solution which originated a long time ago, it may appear to be conflating the problems of the past with similar ones in the present, which is not the intention here. However, while hedgerows are exemplars of nature-based design they were the most sophisticated nature-derived technology of their day and have continued to be into the present era. Therefore, it is suggested here that the production of the highest value nature-based solutions today can benefit from a retrospective examination.

3. Hedgerows as nature-based solutions

From the middle of the 15th century to the beginning of the 20th century field boundaries consisting mainly of hedgerows as well as stone walls were dramatically scaled-out throughout the agrarian landscapes of northern and western Europe in order to address agricultural and agronomic ‘problems’. Field boundaries are the principal element in what defines an enclosed landscape (or sometimes referred to as Bocage), and on good soils hedgerows made up the majority of field boundaries in the agrarian landscape. Hedgerows became to be seen as a visual and visceral element of the modernising of farm system design and management, being based on a landlord and tenant system (more detailed clarifiations on this can be found in: Barr and Petit, 2001; Dowdeswell, 1987; Müller, 2013). The motivation for enclosing what was formerly common land throughout Europe differed from nation to nation, but all followed the paradigm of seeking a simple and scalable solution for agricultural improvement and increased efficiency. For example, hedgerows were systematically planted throughout the British Isles in a series of Enclosure Acts from the 1660s up to the early 1900s, although they had been in use many centuries prior to this in some regions. Hedgerows were used as solutions to: delineate fields for agricultural production (arable and livestock), to be stockproof, to protect produce and livestock from theft and/or sabotage, and to provide shade and shelter to livestock and perhaps to early crops (DI 1598). They were

[2] See: https://www.iucn.org/theme/ecosystem-management/our-work/iucn-global-standard-nature-based-solutions

later redesigned in order to provide landowners with opportunities for sport (e.g. hunting and equestrian activities), with the introduction of a style of hedgerow management known as *hedgelaying*, thus maintaining stockproof fences which can also be used as jumping hurdles. A less appealing solution that the emergence of hedgerows in Europe provided was that they were a mechanism to forcefully enclose formerly common land; essentially privatising land for the wealthy elites (Aalen et al., 1997). This aspect of the solution has a mirror effect in the nature-based solutions of today, where it has been observed that nature-based solutions in, for example, urban areas may have the unintended effect of social exclusion and gentrification (Haase et al., 2017; Song et al., 2019). However, hedgerows certainly provided utilitarian, agricultural solutions as part of their original planning and design.

Hedgerows were not necessarily new elements in the landscape. For thousands of years farm fields throughout the word were bounded by a four kinds of barrier: stone walls, trenches, earth banks, or deadwood fences (Aalen et al., 1997; Angus and Woods, 1987; Dowdeswell, 1987; Jefferies and Looker, 1948; Müller, 2013; Pollard et al., 1974). Some of these ancient field boundaries i.e. stone walls and earth banks are pervasive throughout the world today, and are still in active usage, though often with the addition of a wire or electric fence. Earth banks with trenches were adapted to incorporate living structures, mainly consisting of thorny trees and shrubs, and this is referred to as a hedgerow. Today, it can also mean any linear woodland in the landscape, and is sometimes referred to as a fencerow, especially when relict or unmanaged (Best, 1983; Nabhan and Sheridan, 1977; Sutton, 1992). During the scaling out of hedgerows in the Enclosure period in Europe, specific species (specifically thorny) were prescribed by the approving authorities for maximum stock proofing efficacy as well as ease of implementation and management (Brooks and Agate, 1984; Evens, 1993; Feehan, 2003; FWAG, 1983; Pollard et al., 1974; Sotherton and Page, 1998). So, mirroring the present desire for scalability and co-benefits, hedgerows were required to have set *standards* that the nature-based solution was required to have in order to carry out its function effectively and efficiently. The use of thorny species with some standard trees that were/are of local or native origin meant that hedgerows could be easily propagated and economically scaled out to the wider landscape. What emerged at the same time with the planting of hedgerows was new techniques and specialised tools for hedgerow management, especially the emergence of 'hedgelaying'. This ensured efficient service provision (Brooks and Agate, 1984; Fry, 1994b; Müller, 2013) and in hindsight we can see that the implementation of the nature-based solution approach gave inspired innovation. With the redefining of the landscapes of Europe, as well as other historical changes, field boundaries hedgerows gave rise to new and different uses of the land uses, such as sporting and recreational activities. This is analogous to the potential co-benefits that are aspired to within the nature-based solution approach of today (Frantzeskaki et al., 2019). Therefore, these prototype nature-based solutions spread throughout European landscapes, as well as countries which were later colonised by Europeans, and many persist today where agricultural practices have largely remained unchanged. Some of their original utility such as stock proofing may have diminished (Marshall and Moonen, 2002; Robinson and Sutherland, 2002) due to poor management practices, larger and heavier livestock breeds, colonisation by non-thorny or exotic species, and the loss of management skills and cultural practices (Amy et al., 2015; Arnaiz-Schmitz et al., 2018). However, their legacy remains intact and while we seek to normalise nature-based solutions as a concept, hedgerows can be seen as an exemplar.

4. Emergent co-benefits

With the modernization of agriculture in the 1950s, and the associated decline in biodiversity, much research has been carried out on the values of semi-natural areas in differing landscapes (for example: Ali et al., 2014; Rawes and Hobbs, 1979; Sullivan et al., 2011; Uematsu et al., 2010), and hedgerows have come to the fore with extremely high biodiversity and ecosystem service values, especially as wildlife reserves and corridors (Puth and Wilson, 2001; Roy and de Blois, 2008; Wehling and Diekmann, 2009), and may be considered the earliest recognised green infrastructure (*sensu* Benedict and McMahon, 2006). They have become extremely valued ecologically as linear refuges and genetic reserves for an appreciative and increasing collection of terrestrial flora and fauna species in European agri-environmental landscapes (see: Barr and Petit, 2001; Dover, 2019), especially in light of increasing agricultural intensification, biodiversity loss, and increased hedgerow removal / destruction / over-management (Bates and Harris, 2009; Byrne and delBarco-Trillo, 2019; Chamberlain et al., 1999; Evens, 1993; Froidevaux et al., 2019; Sotherton et al., 1981; Sparks and Martin, 1999; Staley et al., 2015, 2013). There is also a wider body of research on the diverse and newer values of hedgerows in the rural landscape with respect to their potential for intercepting excess diffuse nutrient runoff (Borin et al., 2010; Ghazavi et al., 2008; Grimaldi et al., 2012; Marshall and Moonen, 2002; Thomas and Abbott, 2018; Viaud et al., 2004) as well as pesticide and herbicide drift (Andresen et al., 2012; Froidevaux et al., 2019; Marshall and Moonen, 2002; Ricci et al., 2011; Tiwary et al., 2006). Table 1 is an illustrated example of these emergent values, though there may be many more.

In some countries, for example France, the UK and The Netherlands, where hedgerows were extensively removed from the 1950s onwards hedgerows are now being replanted again as a nature-based solution, though this time they are addressing newly recognised problems such as crop and animal exposure, poor soil stabilization, decline in pollinator repositories, and nutrient / spray drift. They are also being reintroduced to provide co-benefits such as amenity and wild foraging (Barr and Petit, 2001). Hedgerows are also being introduced, in some countries for the first time, to aid with minimizing, for example, snow drift and also for soil / nutrient retention (Marshall and Moonen, 2002; Vought et al., 1995). Those hedgerows that are still extant in their original landscapes have also acquired these additional values. When managed properly, hedgerows may even be valuable in mitigating some of the effects of climate change (Black et al., 2014; Ghazavi et al., 2008; Hernández-Morcillo et al., 2018), especially in urbanising landscapes (Gromke et al., 2016; Vanneste et al., 2020). More recently, hedgerows (or, more appropriately, fencerows) have been appearing in urban areas and along motorways, though not morphologically too different to field boundary hedgerows, where they have been shown to intercept particulate matter, chemicals and noise (Tiwary et al., 2006, 2008), which can mitigate other societal challenges especially when it comes to human health.

5. Discussion

A standalone hedge is *a* nature-based solution. However, when combined with numerous interlaced hedgerows to form an enclosed landscape, hedgerows become more effective nature-based solutions providing multiple, cumulative co-benefits at a landscape scale. So, drawing from the list of co-benefits shown in Table 1 and applied to the IUCN proposed framework for nature-based solutions (c.f. Cohen-Shacham et al., 2016), todays' hedgerows mirror fit well into this framework because they:

1 Embrace nature, as discussed above where hedgerows have emerged as highly important for conservation in the agrarian landscapes in which they are located;
2 Can be stand-alone or integrated with other hedgerows or landscape elements, as can be seen where new hedgerows are being planted to provide a variety of local and landscape solutions;
3 Are site- and culturally-specific, having drawn upon and also created new skills and knowledges;
4 Have produced, and continue to produce, broader societal benefits, especially in the areas of recreation, tourism, and on-farm diversification;

Table 1
This table illustrates how hedgerows have exceeded the intent of their original nature-based solution (enclosure/exclosure) and a wider number of newly recognised co-benefits have emerged with the advent of increased and concerted research being carried out into these field boundaries and into the values that nature has for society.

Early history & Enclosure era Hedgerows as engineered solutions for…	Modern era		
	Hedgerows providing ecological solutions, such as…	Hedgerows providing co-benefits, such as…	Hedgerows providing engineered solutions, such as…
Enclosing agricultural fields and preventing livestock from wandering / intermingling / theft (Aalen et al., 1997; D., I., 1598; Feehan, 2003; Kelly, 1997; Marshall and Moonen, 2002; Morgan Evans, 1994; Nairn and O'Sullivan, 1977; Pollard et al., 1974)	***Providing general wildlife corridors and habitat linkages*** (Davies and Pullin, 2007; Dawson, 1994; Dondina et al., 2016; Forman and Baudry, 1984; Fry, 1994b; Krewenka et al., 2011; Marshall and Moonen, 2002; Maudsley, 2000; Smart et al., 2001)	***Amenity, foraging and hunting*** (Aebischer et al., 1994; Bunce et al., 1994; Burel and Baudry, 1990; Nozedar, 2012; Rands and Sotherton, 1987)	***Preventing snowdrift*** (Iversen, 1981; Walter et al., 2004)
Providing shelter and shade to livestock from sun and exposure (An Taisce, 2000; D., I., 1598; Greaves and Marshall, 1987a; Marshall and Moonen, 2002; Pollard et al., 1974; Staley et al., 2012)	***Biodiversity repositories / wildlife habitat provision*** (Burel, 1992; Graham et al., 2018; Greaves and Marshall, 1987a; Lecq et al., 2017; Petrides, 1942; Smart et al., 2001; Staley et al., 2015; Vickery et al., 2002)	***Food and fuel for human use*** (An Taisce, 2000; Baudry et al., 2000a; Biber, 1988; Nozedar, 2012; Reif and Schmutz, 2001)	***Improving microclimate*** (Gardiner and Dover, 2008; Guyot and Verbrugghe, 1976; Harvey, 1976; Sánchez et al., 2009; Sánchez and McCollin, 2015)
Providing shelter and shade to livestock from wind and rain (Brown et al., 2004; Burel and Baudry, 1990; Carborn, 1976; D., I., 1598; Helps, 1994; Pollard et al., 1974)	***Habitats for reptiles and amphibians*** (Edgar et al., 2010; Lecq et al., 2017; Saint-Girons and Duguy, 1976; Vos et al., 2007)	***Screening buildings*** (An Taisce, 2000; BASC, 1996; Biber, 1988; Millsopp, 2001)	***Intercepting particulates*** (Gromke et al., 2016; Ottosen and Kumar, 2020; Tiwary et al., 2006, 2008)
Delineating between agronomic activities (Baudry et al., 2000b; D., I., 1598; Feehan, 2003; Greaves and Marshall, 1987a)	***Habitats for mammals*** (Boughey et al., 2011; Gelling et al., 2007; Koyzageorgis and Mason, 1997; Lacoeuilhe et al., 2016; Michel et al., 2007;	***Generating a cultural link to past and folk memory*** (Dowdeswell, 1987; Morgan Evans, 1994; Nairn and O'Sullivan, 1977; Oreszczyn, 2000; Oreszczyn and	***Improving soil drainage*** (An Taisce, 2000; Ghazavi et al., 2008; Harvey, 1976; Millsopp, 2001; Miñarro and Prida, 2013)

Table 1 (*continued*)

Early history & Enclosure era Hedgerows as engineered solutions for…	Modern era		
	Hedgerows providing ecological solutions, such as…	Hedgerows providing co-benefits, such as…	Hedgerows providing engineered solutions, such as…
	Peña et al., 2003; Poulton, 1994; Tew, 1994)	Lane, 2000; Oreszczyn et al., 2010; Sánchez and McCollin, 2015)	
	Habitats for birds / migratory birds (Arnold, 1983; Batáry et al., 2010; Besnard and Secondi, 2014; Gottschalk et al., 2010; Green et al., 1994; Heath et al., 2017; Hinsley and Bellamy, 2000; Lack, 1992; Lysaght, 1990; O'Connor and Shrubb, 1986; Osborne, 1984; Pain and Pienkowski, 1997; Vickery et al., 2002; Vickery et al., 2009)	***Marking political and social boundaries in the landscape*** (An Taisce, 2000; Angus and Woods, 1987; Garratt et al., 2017; Moxham, 2001)	***Intercepting agricultural spray drift*** (Brown et al., 2004; Burel and Baudry, 1990; Lazzaro et al., 2008; Longley et al., 1997; Longley and Sotherton, 1997; Marshall and Moonen, 2002; Moonen and Marshall, 2001)
	Repositories for vascular plants (Bunce et al., 1994; Fritz and Merriam, 1993; Fry, 1994b; Helliwell, 1975; McCollin et al., 2000a; Vanneste et al., 2020; Wehling and Diekmann, 2009; Wilson, 1994)	***Producing healing plants*** (Angus and Woods, 1987; Dowdeswell, 1987; Nozedar, 2012; Podlech, 1996)	***Reducing soil blow*** (Fry, 1994a; Greaves and Marshall, 1987b; Pollard et al., 1974)
	Seed reserves and genetic heritage (Favre-Bac et al., 2014; McCollin et al., 2000b; Smart et al., 2001; Staley et al., 2013; Wilkerson, 2014) Bunce et al., 1993 Cummins & French, 1994	***Creating cultural distinctiveness*** (Barr and Petit, 2001; Baudry et al., 2000a, b; Burel and Baudry, 1995; Feehan, 2003; Nairn and O'Sullivan, 1977)	***Buffering flood and soil erosion*** (Ghazavi et al., 2008; Greaves and Marshall, 1987b; Merot, 1999; Montégut, 1986; Vickery et al., 2009)
	Supporting pollinating invertebrates (Dover and Sparks, 2000; Dover et al., 2000; Dover, 1997; Garratt et al., 2017; Hannon and Sisk, 2009;	***Screening human activities*** (An Taisce, 2000; Dowdeswell, 1987; Nairn and O'Sullivan, 1977)	***Prevention of wetland pollution from runoff*** (Borin and Bigon, 2002; Caubel et al., 2003; Grimaldi et al., 2012; Moxham, 2001; Thomas and Abbott, 2018; Viaud et al., 2005, 2004; Vought et al., 1995)

(*continued on next page*)

Table 1 (*continued*)

Early history & Enclosure era	Modern era		
Hedgerows as engineered solutions for…	Hedgerows providing ecological solutions, such as…	Hedgerows providing co-benefits, such as…	Hedgerows providing engineered solutions, such as…
	Lebeau et al., 2018; Lewis, 1969; Miñarro and Prida, 2013; Morandin and Kremen, 2012, 2013; Mwangi et al., 2012)		
	Shelter for overwintering and predator invertebrates (Holland et al., 2001; Miñarro and Prida, 2013)	***Dividing soil types / cropping patterns*** (Dowdeswell, 1987; Nairn and O'Sullivan, 1977)	***Limiting evapotranspiration*** (An Taisce, 2000; Biber, 1988; Greaves and Marshall, 1987b; Longley et al., 1997; Merot, 1999; Pollard et al., 1974)
	Supporting other invertebrates (Amy et al., 2015; Lacoeuilhe et al., 2016; Le Viol et al., 2008; Lebeau et al., 2018; Ricci et al., 2011)	***Providing craft materials*** (Baudry and Bunce, 2001; Baudry et al., 2000a; Koyzageorgis and Mason, 1997)	
	Fungi reserves (Dowdeswell, 1987; Montégut, 1986)		

5 Are a repository of biodiversity, and have been demonstrated to both maintain diversity and also have evolved new ecological values over a longer timeframe;
6 Are applied at a landscape scale, and indeed have shaped or defined the landscapes we see today;
7 Have come to symbolise the move from economic progress when they first appeared, to now providing a wide range of ecosystem services and natural capital; and
8 Are resurging as nature-based solutions today, with the adoption of new policies and actions for biodiversity and cultural conservation, as well as other environmental concerns.

Therefore, an historical perspective on hedgerows as prototype nature-based solutions reveals some illustrative but not exhaustive commonalties between a nature-based solution of the past and those that are aspired to today. Nature-based solutions need to be planned and engineered for long-term, measured and effective impact, and specific management is required to ensure this long-term efficacy and efficiency. The scaling of nature-based solutions can generate multiple co-benefits, including complimentary innovations such as the development of new management, collaboration and planning skills and creating opportunities for specialised nature-based enterprises. The comparisons diminish as we look at the current push for scaling nature-based solutions, because hedgerows were not originally designed to address environmental and climate change, issues of health well-being and community cohesion, and so on. Indeed, current nature-based solutions in Europe are principally prescribed under the climate change adaptation and mitigation agendas and are therefore designed to meet specific environmental challenges but also co-created to fulfil societal challenges (EC, 2015).

The question that emerges is: what lessons can be learnt from looking at a nature-based solution that was devised several centuries ago? Is it possible to discern the potential opportunities that modern nature-based solutions can provide, and perhaps predict key indicator traits that may be expected to emerge over time, to ensure that the nature-based solutions of today continue to have appreciative and measurable impact beyond their foreseen duties? The following characteristics emerge as key indicators of a nature-based solution that is cost effective, simultaneously providing multiple co-benefits, and builds resilience (EC, 2015). A nature-based solution should:

1 Utilize, where possible, **indigenous** and **resilient** species or species of local origin with **specific characteristics** of value as solutions (e.g. thorniness);
2 Be scaled out using simple, ecologically adapted, and **replicable** construction, which can be **cost effectively managed**;
3 Be designed for **multifunctionality** so as to derive multiple gains from the same solution over time and across the landscape;
4 Create an infrastructure that **appreciates in value** over time and that spawns the development of new specialised skills and enterprises;
5 Efficiently **compete** with non-nature-based solutions or engineered solutions and can be **demonstrated** to do so through monitoring over the long term;
6 Facilitate the **reorientation** of the landscape or cityscape towards a greening or renaturing paradigm that is more diverse and resilient; and
7 Create opportunities for **innovations** such as those that emerge on the planning and management side, as well as those derived from the co-benefits.

Though not exhaustive, these characteristics point towards the constituents of what a nature-based solution may need in order to be considered to be successful in the long-term and achieve the high demands that are ascribed to them. What this list lacks is the more modern collaborative, co-creative aspect of nature-based solutions, which was absent during the imposing of hedgerows on the landscape in much of the past and which is proving difficult to embed in the nature-based solutions process today (Dumitru et al., 2020; Frantzeskaki et al., 2020). Co-creation and co-design clearly go a long way towards ensuring as successful project as can be seen by the successful scaling of nature-based solutions in the more studies urban copntext (Mauser et al., 2013; Voorberg et al., 2015) and should address some of the negative aspects of nature-based solutions.

6. Conclusion

There is a growing expectation around nature-based solutions. Though this is a recently introduced term, nature-based solutions are the focus of potentially innovative moves to mainstream nature and conservation into all aspects of human endeavour. Because nature may not normally be seen by society as having the competitive abilities to tackle modern problems in the timeframe needed, it is difficult to make a case for nature-based solutions as a panacea. However, it is perhaps timely to reflect and re-evaluate some of nature-based innovations that earlier societies devised to tackle the era-specific problems of their time; also viewing nature as a viable solution. Using the perspective of hindsight, this paper offers a scenario where a type of nature-based solution may ultimately take us. Hedgerows were and are widely used as a viable solution for marking boundaries and for retaining and protecting livestock. It is clear that over the centuries where they have remained in the landscape that solution is still being supplied, except that they have now acquired multiple planned and unplanned co-benefits that are emerging in the present and may continue to emerge in years to come. The link between historical nature-based solutions and those being promoted today is somewhat contrived, mainly because of the advancements in understanding in the intervening centuries and the societal changes in the intervening years. However, this perspective serves to offer

inspiration for the adopting of the nature-based solution approach based on the lessons that can be elicited from the case of hedgerows. It is intended to also offer a benchmark for practitioners, designers and managers to stimulate the kind of temporal and lateral thinking that is required to derive the kinds of co-benefits that will put 'nature' into nature-based solutions.

Declaration of Competing Interest

The authors declare no conflict of interest.

Acknowledgements

This authors' research into nature-based solutions is supported by funding from the European Community's Framework Program Horizon 2020 for the Connecting Nature Project (grant agreement no. 730222), the ReNature project (grant agreement No 809988) and the GoGreen Routes project (grant agreement no. 868764).

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.envsci.2021.02.008.

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