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Article Title:

Rewilding and the water cycle

Article Category:

● PERSPECTIVE
○ ADVANCED REVIEW
○ PRIMER
○ FOCUS ARTICLE
○ OVERVIEW
○ SOFTWARE FOCUS

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Conflict of Interest

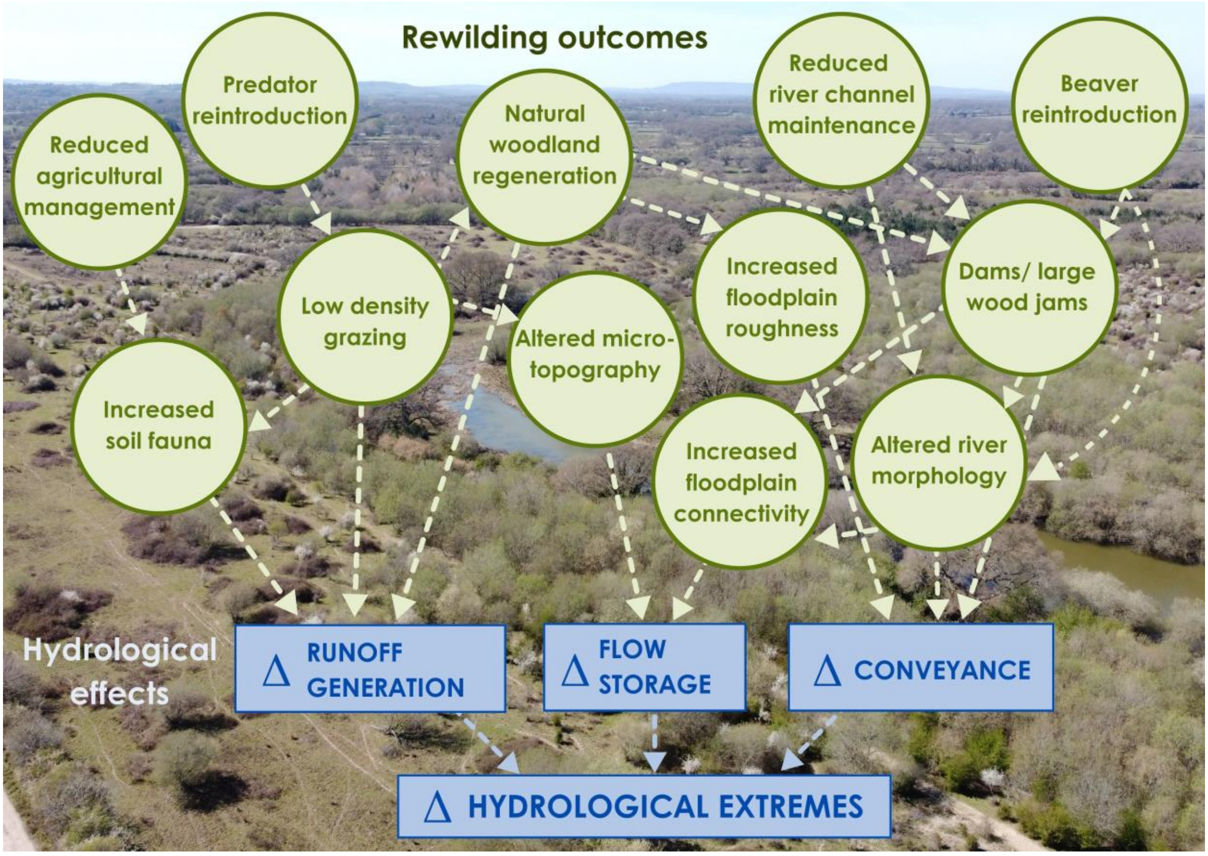
No conflict of interest

Abstract

Rewilding is a radical approach to landscape conservation that has the potential to help mitigate flood risk and low flow stresses, but this remains largely unexplored. Here, we illustrate the nature of hydrological changes that rewilding can be expected to deliver through reducing or ceasing land management, natural vegetation regeneration, species (re)introductions and changes to river networks. This includes major changes to above- and below-ground vegetation structure (and hence interception, evapotranspiration, infiltration and hydraulic roughness), soil hydrological properties and the biophysical structure of river channels. The novel, complex, uncertain and longer-term nature of

rewilding-driven change generates some key challenges, and rewilding is currently relatively constrained in geographical extent. Significant changes to the water cycle that benefit people and nature are possible but there is an urgent need for improved understanding and prediction of rewilding trajectories and their hydrological effects, generation of the knowledge and tools to facilitate stakeholder engagement and an extension of the geography of rewilding opportunities.

Graphical/Visual Abstract and Caption



Rewilding is an ambitious approach to environmental restoration at large scales with a range of potential hydrological effects. As a result, there is potential for rewilding to help mitigate flood and low flow issues, but this is underexplored. Some key challenges should shape the future research agenda.

1. INTRODUCTION

Increasing recognition of the benefits of working with natural processes has provided more sustainable approaches to mitigating hazards, maximising ecosystem services and increasing resilience to climate change. Nature-based Solutions (NbS) include a wide range of actions that work with natural processes to protect, restore or more sustainably manage ecosystems in order to deliver benefits for both people and biodiversity and address the global challenges of climate change and biodiversity loss (Seddon et al. 2020). NbS have been advocated as cost-effective and potentially 'superior' land management solutions with potential to become mainstream (Keestra et al., 2018). Some forms of NbS focus on the mitigation of hydrological extremes (primarily floods, but potentially also low flow stresses) by manipulating the way runoff moves through river catchments, and are termed Natural Flood Management (NFM) in the UK (Lane, 2017). NFM uses more natural hydrological and geomorphological processes and features (as opposed to engineering methods) to attenuate river discharge or 'slow the flow', reducing flood hazard as a primary goal, but also potentially alleviating low flow issues (see Lane, 2017; Dadson et al., 2019 for reviews and evidence summary). The latter, however, is rarely explored and likely more complex (Harvey et al., unpublished data), hence our discussions in this paper focus primarily on mitigation of high flows. NFM measures aim to (i) reduce rapid runoff on hillslopes by increasing the proportion of runoff that takes slower flow pathways through the landscape (e.g. strategic planting of woodland and tree shelterbelts), (ii) increase temporary storage of water (e.g. in wetlands and retention ponds) and (iii) impede the conveyance of water in river channels (e.g. through river restoration and using wood jams as 'leaky barriers') (Lane et al., 2007; O'Connell et al., 2007; Salazar et al., 2012; Lane, 2017; Dadson et al., 2019; Wren et al., 2022). A key principle of NFM, therefore, is the spatial reorganisation of flow pathways and floodplain inundation to retain water in the landscape 'upstream' and attenuate discharge further downstream (Lane, 2017). Measures that 'slow the flow' and encourage floodplain storage also have the potential to deliver wider benefits for biodiversity, nutrient cycling, carbon sequestration and communities (Lane, 2017; Wilkinson et al., 2019; Lo et al., 2021) although these are less well researched and understood.

Rewilding, another form of NbS, has been rapidly gaining momentum over similar timescales to NFM. Rewilding has numerous definitions that have developed over the last two decades (Jørgensen, 2015; Svenning et al., 2016) and elicits excitement and controversy in the scientific and public realms. It is generally accepted that rewilding emphasises working with natural processes to establish self-sustaining ecosystems. It is process-led, large scale (e.g. 10 - 10,000+ km^2; Lawton, 2010), focused on ecosystem function rather than composition or target species, emphasises the role of animals as agents of landscape change (Sidebar 1), appeals to an ethic of coexistence and values multiple benefits to ecosystems and ecosystem services (Pettorelli et al., 2017; Derham et al., 2018). Rewilding approaches have, to date, largely focused on former agricultural land and include ‘passive rewilding’, i.e., the withdrawal of (usually agricultural) land management, and more active approaches that incorporate species reintroductions (or exclusions). Many reintroduced or recolonising species are effective ecosystem engineers, modifying habitats and resource flows (see Sidebar 1). Most rewilding definitions now de-emphasise the idea of restoring to an historic ideal and as a result, ‘wilding’ is perhaps a more appropriate term (Tree, 2018). Here, we retain ‘rewilding’ for transferability, and likewise use the term ‘restoration’ as a catch-all term for improvements towards more natural function.

Rewilding-driven landscape change will alter key elements of the water cycle, with potential to influence hydrological extremes through similar process mechanisms to NFM measures. Yet hydrologists have been underrepresented in the rewilding community and literature to date, (e.g., Bakker and Svenning, 2018; Figure 1), and hydrological benefits have been assumed but remain largely unquantified. In this paper, we illustrate the nature of hydrological changes that rewilding can be expected to deliver as rewilding projects expand and evolve over the coming decades. Since existing evidence from rewilding contexts is limited, we use this in combination with examples from analogue landcover change contexts (e.g. sustainable land management). We explore how the nature of rewilding-driven change generates some challenges in relation to its potential to help mitigate hydrological extremes. We use these challenges to propose a future agenda for research on rewilding and the water cycle.

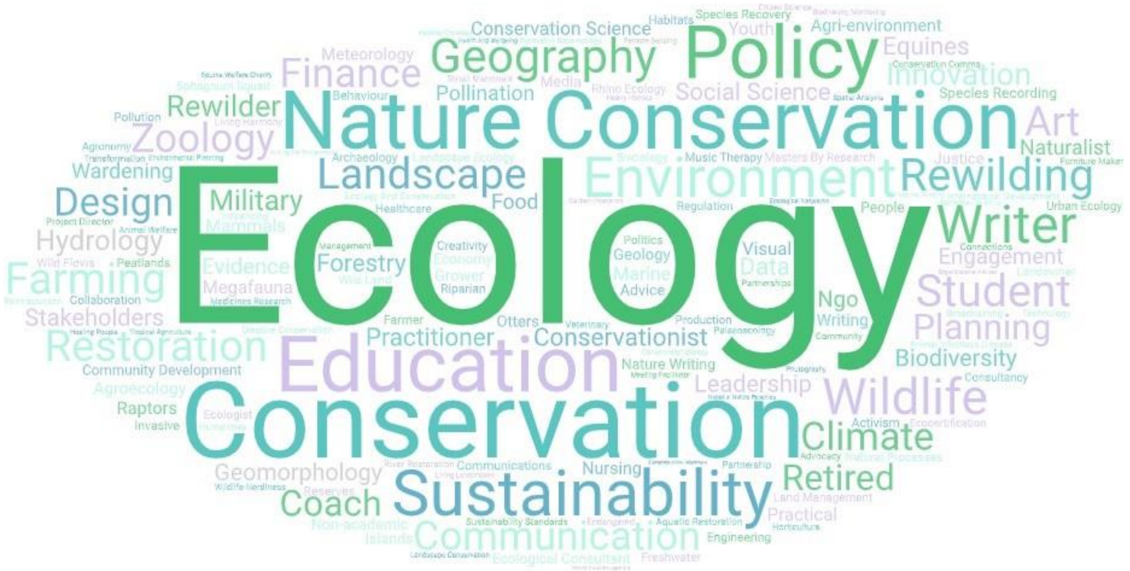


Figure 1 Word cloud generated by audience responses to authors' request for "areas of expertise or academic disciplines that best describe your work" at the UK conference *Rewilding and its effects on nature and people* (Cambridge Conservation Forum, 2019).

Sidebar title: The role of ecosystem engineers in rewilding

A concept central to rewilding is the transformation of landscapes and ecosystem processes by vegetation and animals. Ecosystem engineers are plants and animals that create, maintain and transform habitats, and modulate ecosystem resource flows (Jones et al., 1994: Polvi and Sarneel, 2018). It has been suggested that environmental restoration that utilises ecosystem engineers can produce higher levels of ecosystem functioning, and greater restoration success more quickly than approaches that do not leverage ecosystem engineers (Bailey et al., 2018). Some ecosystem engineers are described as keystone species, referring to their disproportionately large effects on the environment relative to their abundance (e.g., beavers; Brazier et al., 2020). But smaller, less conspicuous animals such as invertebrates occurring in larger numbers can cumulatively generate substantial ecosystem engineering effects (Haussman, 2017). A range of ecosystem engineering plants and animals influence runoff processes and flow conveyance and can attenuate flood risk (e.g. Westbrook et al., 2020) or exacerbate it (e.g. Harvey et al., 2019).

2. CHANGES ARISING FROM REWILDING

2.1 Wilder landscapes: reduced land management and natural vegetation regeneration

Passive rewilding of agricultural land through withdrawal of management enables natural vegetation regeneration, transforming land cover from arable crops or grazed grassland to more complex mosaics of grassland, scrubland and woodland in temperate environments (Begueria et al., 2003; Tree, 2018; Figure 2a). This generates year-round vegetation cover and species assemblages with varied canopy and root structure which can be expected to reduce the risk of 'muddy floods' linked with arable land use (c.f. Boardman, 2003). Exclusion or reduced densities of grazing animals are known to alleviate problems with soil compaction, increase soil infiltration rates and reduce runoff and soil erosion (Henshaw et al., 2013; Marshall et al., 2014). Allowing drains to vegetate and infill over time, or actively blocking them under a rewilding scheme may reduce hydrological connectivity and flow conveyance and hence slow the movement of water through the landscape in a similar way to the revegetation or blocking of drainage ditches in forestry and peatland systems (Price et al. 2003; Robinson and Dupeyrat, 2005).

New and diverse vegetation canopies arising from rewilding will alter rates of interception of precipitation and evapotranspiration relative to former agricultural landcover. This type of landcover change can occur through land abandonment and has been linked with reduced runoff at local and catchment scales (Llorens et al., 1997; Begueria et al., 2003; Cerdà et al., 2019), although there is likely a limit to which increased tree cover can mitigate very high magnitude, economically damaging floods (e.g. Soulsby *et al.*, 2017). The complex root networks associated with woody vegetation influence soil structure and create macropores and have been linked with substantial increases in soil infiltration rates and the potential to help reduce runoff and flood peaks (Carroll et al. 2004; Marshall et al., 2014). In contrast, however, large scale afforestation has been linked with increased low flow issues through increased catchment evapotranspiration (Buechel et al., 2022).

The elimination or reduction of fertilisers and pesticides under rewilding schemes can be expected to increase the abundance and diversity of soil fauna (e.g. earthworms, dung beetles, ants) that are known to contribute to increased infiltration rates and subsurface flow by creating void space and altering particle size and composition, macropore frequency, soil infiltration rates and soil moisture storage and hence potentially reduce runoff (van Schaik et al., 2013; Spurgeon et al., 2013; Andriuzzi et al., 2015; Chen et al., 2022 Figure 2b). These types of hydrological change can help mitigate the effects of drought as well as intense rainfall events, through improved water retention and modulation of precipitation extremes (Velduis et al., 2014; Johnson et al., 2015; Andruizzi and Hall, 2018).

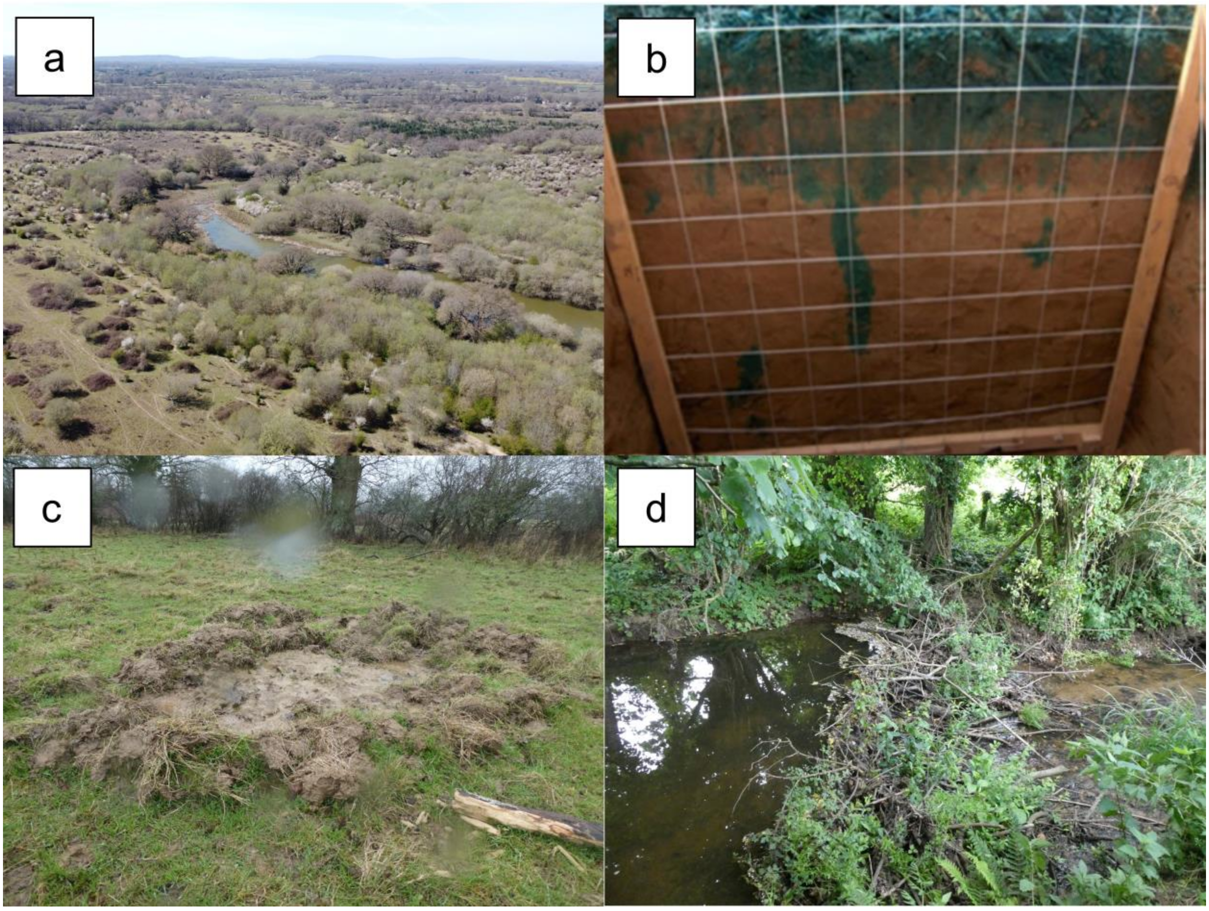


Figure 2 Examples of different types of ecosystem engineering effect on hydrological processes: (a) vegetation regeneration arising from passive rewilding and natural grazing (Knepp Estate, UK); (b) soil fauna such as earthworms can increase macropore frequency, soil infiltration rates and soil moisture storage capacity (reproduced from van Schaik et al. 2013, with permission) (c) rootling by pigs can alter soil characteristics and generate mesohabitats for pioneer woody species (Knepp Estate, UK); (d) beaver dams modify instream processes and floodplain connectivity, altering water storage and conveyance (River Otter, UK).

2.2 Wilder landscapes: species reintroductions

Reintroduction of free roaming large herbivores (cattle, ponies, deer, pigs, bison) is a common component of landscape rewilding. Introduction of non-commercial breeds at lower stocking densities than traditional intensive grazing reduces soil compaction, increases infiltration rates and reduces runoff in grazed pastures (Marshall et al., 2014; Lai et al., 2020). There is also potential for ‘hotspots’ of soil compaction, however: free roaming animals may be concentrated in the landscape according to preferences, behaviours and interactions, concentrating flow pathways and increasing runoff in impacted locations (Meijles et al., 2015). Large herbivores can create heterogeneous mosaics of vegetation (Figure 2a) through their different feeding mechanisms: grazing short vegetation (e.g. cattle, bison), browsing higher-growing woody vegetation (e.g. deer) and rootling the soil (pigs; Figure 1c) (Vermeulen, 2015; Tree, 2018). This ecosystem engineering activity removes plant biomass, changes vegetation structure, increases light at ground level, bioturbates the soil and disperses seeds (Derham et al., 2018). There is a dearth of evidence on hydrological impacts of large herbivore-mediated vegetation change at rewilding sites, but these can be expected to include changes to interception, evapotranspiration and infiltration rates via above-ground changes to canopy structure, below-ground changes to root networks and soil fauna changes that affect soil structure and macropore development. Feedbacks between above-ground (e.g. large herbivores) and below-ground (e.g soil fauna) changes arising from rewilding create contrasting and spatially heterogeneous effects on soil structure (Howison et al., 2017; Andruizzi and Hall; 2018). Direct soil bioturbation impacts from animals can also arise from feeding and other activities. For example, pig rootling disturbs the upper soil layers and creates depressions in the soil surface enabling germination of woody species (Figure 2c; Tree, 2018) and bison wallows can create ephemeral wetland patches (Knapp et al., 1999), although the wider hydrological significance of these impacts is not understood. Some reintroduced ecosystem engineers can increase soil turnover and dig areas that are not excavated by other species, potentially contributing to soil restoration, for example the reintroduction of the locally extinct Tasmanian Bettong (Munro et al., 2019). The nature of hydrological changes will reflect a range of factors including landscape and climate characteristics, the assemblage of herbivores introduced, the timing of their introduction, and their behaviours, movements and interactions, and these factors remain largely unexplored.

Keystone species reintroductions can generate hydrological change indirectly via trophic cascades triggered by apex predators. An often-cited example is the reintroduction of wolves to Yellowstone USA, which has been linked with the initiation of a tri-trophic cascade involving wolves, elk and cottonwoods. The presence of wolves has been attributed to changes in elk behaviour that facilitated re-establishment of riparian vegetation and altered soil structure, bank erosion and river planform (Ripple et al., 2001; Laundre et al., 2001; Beschta and Ripple, 2015), thus altering the routing of water flows through the catchment. Similar trophic cascades attributed to wolf reintroductions have been observed in Wisconsin, USA and Poland (Callan et al., 2013; Kuijper et al., 2013). Eurasian lynx are also efficient predators that can reduce or displace populations of browsing herbivores (Andrén and Liberg, 2015), with potential for knock-on effects on vegetation regeneration and woodland structure (Mysterud and Ostbye, 2004) and hence hydrological processes, although this remains unexplored.

2.3 Wilder river systems

Rewilding creates space in the landscape for wilder river systems, which in turn will influence the routing of flows through river networks and opportunities for floodplain storage via floodplain land cover change, reduced channel management, species reintroductions (e.g. beaver) and more radical approaches to river restoration (e.g. 'Stage Zero' restoration; Cluer and Thorne, 2013). Withdrawal or reduction of traditional operational 'maintenance' of river channels such as the removal of instream and riparian vegetation including large wood will increase the frictional resistance (roughness) of the river channel, slowing the flow, raising water levels and increasing the potential for floodplain inundation and storage under high flows (Darby and Thorne,1995; Addy and Wilkinson, 2019). Similarly, floodplain vegetation regeneration increases the hydraulic roughness of the floodplain, reducing the velocity of overbank flows (Thomas and Nisbet, 2007; Dixon et al., 2016) and hence contributing to a 'slowing of the flow' through the landscape. Over longer timescales, riparian vegetation regeneration arising from landscape rewilding in the wider catchment will increase supply of woody material to river channels and the formation of wood jams that increase roughness and afflux and encourage floodplain storage (Addy and Wilkinson, 2019; Dixon et al., 2019). The quality of floodplain storage and changes to conveyance will be influenced by the vegetation in the riparian zone and wider river corridor, soil types and management.

Beaver reintroductions to river systems are occurring in European catchments where the Eurasian beaver was previously extirpated. In some catchments beaver reintroductions represent a primary focus for ecosystem restoration (e.g., Elliot et al., 2017; Jones and Campbell-Palmer, 2014), while in other areas beaver reintroductions form part of a wider rewilding vision that also includes passive rewilding and/or natural grazing elements (e.g. Tree, 2018). Beaver are impressive ecosystem engineers that generate landscape-scale hydrological and geomorphological change (Brazier et al., 2020). This includes the effects of beaver dams on conveyance (Figure 2d), increased water storage in beaver ponds and floodplain wetlands (Puttock et al., 2017), and extensions of the channel network via excavation of canals in the floodplain (Grudinski et al., 2020). These changes can attenuate flood peaks downstream by reducing conveyance and facilitating inundation and water storage in upstream areas (Nyssen et al., 2011; Puttock et al., 2017; Westbrook et al., 2020). Importantly, flow attenuation effects of beaver pond sequences have been observed for extreme high magnitude events as well as smaller magnitude floods (Nyssen et al., 2011; Westbrook et al., 2020) and beaver damming has also been shown to alleviate low flows (Puttock et al., 2017). Reintroduction of keystone species such as beaver relies on availability of appropriate habitat and food resources, meaning that in some areas successful reintroductions may require prior vegetation regeneration through other rewilding strategies (section 2.1 and 2.2). Other animals also have the potential to alter river system form and behaviour. For example, trampling, trails and ramps created by large animals have been shown to alter drainage networks (e.g. hippopotamus in Tanzania; Deocampo, 2002) and increase propensity for river cut-offs or avulsions (e.g. cattle; Trimble, 1995).

In many catchments, long legacies of anthropogenic modification of the floodplain and river channel influence cultural perceptions of ‘natural’ river systems. For example, Brown et al. (2018) show that early-mid Holocene streams in Europe were likely multi-thread wetland or woodland systems heavily influenced by instream and riparian vegetation, contrasting considerably with prevailing cultural perceptions of natural rivers as single-thread meandering systems with elevated floodplains. There is now increasing interest in more radical approaches to river restoration in Europe and North America that aim to recreate complex multi-thread channel systems by withdrawing channel maintenance operations (e.g. desilting), reintroducing beaver, or directly introducing large woody material (Cluer and Thorne, 2013; Brown et al., 2018). The resulting complex channel morphology creates stronger river-floodplain connectivity and hence potential for floodplain storage. Wilder river systems of this type, however, may not align with existing valuable habitats that have developed in single thread systems in anthropogenically disturbed landscapes (e.g. chalk streams).

3. CHALLENGES AND OPPORTUNITIES

The above discussion outlines the ways in which rewilding approaches create vegetation, soil and river network changes that have the potential to alter hydrological pathways, fluxes and sequencing within river catchments by influencing runoff generation, flow storage and conveyance. These are summarised in a preliminary conceptual model in Figure 3, to support future testing and refinement of hypotheses. Such changes to local hydrological processes may have local benefits and/or costs but the extent to which these can drive meaningful reductions in flood risk or alleviate low flow stresses at catchment scales is largely unexplored. It is also a challenging question to address, since effects on peak or low flows are influenced by spatial scale, event type and catchment characteristics as well as the nature of landcover changes and their spatial configuration (Dixon et al., 2016; Gao et al., 2018; Bathurst et al., 2020; Buechel et al., 2022). For instance, the effects of increasing tree cover may be reduced by the characteristics of the underlying soils (Geris et al., 2015). Similar challenges apply to research on other NbS approaches and NFM measures (Iacob et al., 2017; Metcalfe et al., 2018; Ferguson and Fenner, 2020; Raška et al., 2022), so hydrological research on rewilding can helpfully contribute to debates in this area. Rewilding differs from other NFM style changes in motivation (mitigating hydrological extremes is not the primary motivation), in spatial scale (rewilding is often, although not always, larger-scale) and management intensity (rewilding is a more passive approach compared to key NFM measures such as tree planting, construction of storage ponds and installation of wood jams). As a result, there are a series of challenges more specific to rewilding-driven change that need to be addressed in order to understand and realise the effects on hydrological processes and extremes.

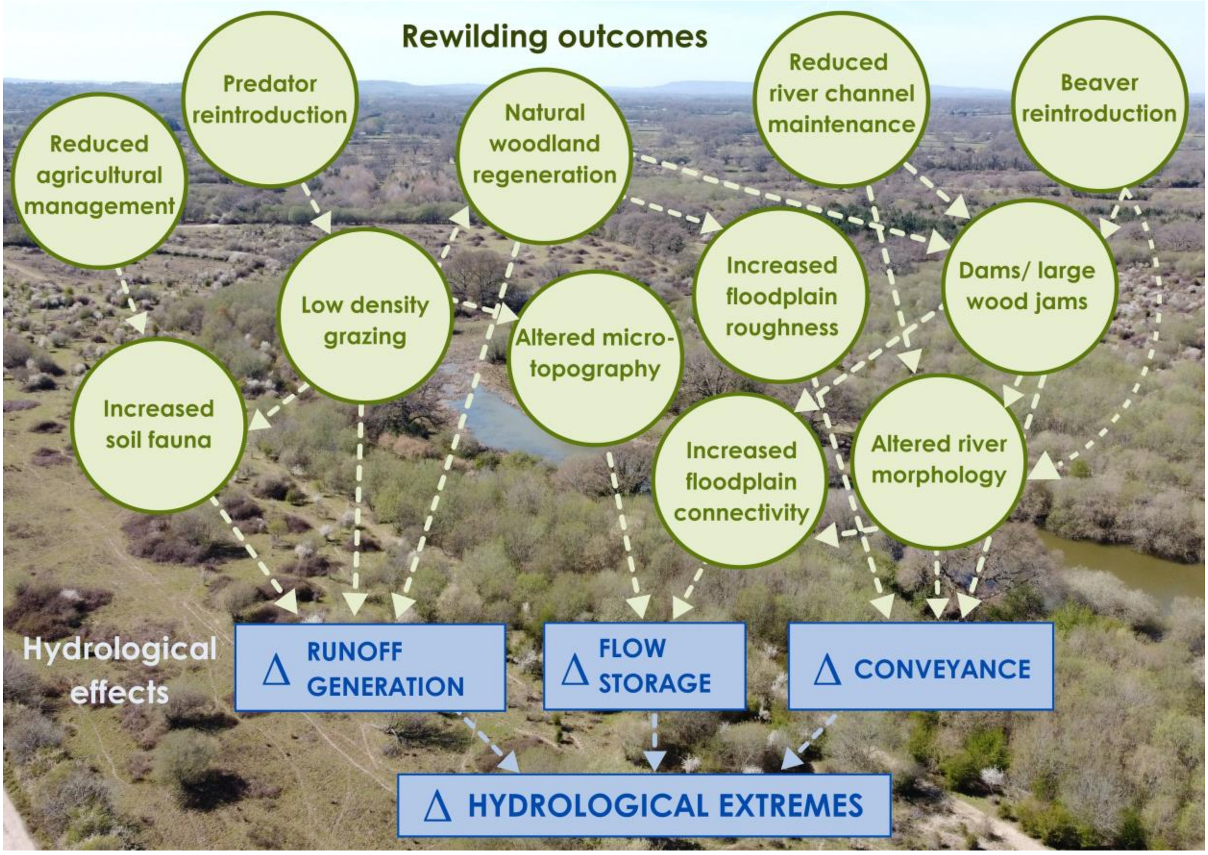


Figure 3 Preliminary conceptual model illustrating the diversity of rewilding outcomes and their expected interaction with runoff generation, water storage and conveyance within catchments. The dotted arrows show connections between processes but there are currently significant uncertainties associated with the directionality and strength of effects as a result of limited direct evidence. The photograph shows a lowland rewilding landscape with vegetation regeneration mediated by large herbivores (Knepp Wildland, UK).

3.1 Challenge 1: rewilding-driven change is novel and heterogeneous

The ecosystems created by rewilding are different to, and 'messier' than, many pre-existing rural landscapes and perceived natural ideals (Tree, 2018). They also differ from land cover types for which much of our existing hydrological understanding has been developed (Morris and Wheater, 2007). The hydrological effects of landcover change and landscape restoration are influenced by a range of factors including topography, climate and legacy of previous land use (e.g. Spencer and Harvey, 2012; Henshaw et al., 2013) and are spatially varied: the same will apply to rewilding-driven change. For example, increased interception, infiltration rates and reduced runoff associated with woody vegetation regeneration can contribute to 'slowing the flow' and reducing erosion (Llorens et al., 1997; Monger et al., 2022) but contrasting effects may occur at local scales, such as soil compaction through large herbivore trampling (Meijles et al., 2015), or river bank erosion generated by beaver burrowing (Brazier et al., 2020). This spatial heterogeneity may generate contrasting effects at smaller scales within catchments, with implications for hydrological extremes.

Cause for optimism may lie in the fact that rewilding emphasises large spatial scales (typically 10 - 10,000+ km^2; Lawton, 2010), creating the potential for net benefits to emerge at the landscape scale. For example, ecosystem engineering activities of beavers create local erosional (e.g. burrowing) and depositional (e.g. beaver ponds) geomorphological effects that vary in space (Brazier et al., 2020). Likewise, beaver dams increase floodplain inundation and water storage locally which delivers an attenuating effect downstream (Puttock et al., 2017). When considered at the landscape scale, however, it is generally accepted that beavers have net storage and attenuation effects on water and sediment fluxes that attenuate floods and low flows (Brazier et al., 2020), and larger-scale sequences of ponds and wetlands can attenuate even high magnitude floods (Nyssen et al., 2011; Westbrook et al., 2020). Thus, we might anticipate that sufficiently ambitious, large-scale rewilding could deliver flood risk and/or low flow benefits at larger spatial scales and ‘net gain’ at the catchment level, provided that any contrasting effects at local scales can be accepted or adaptively managed.

3.2 Challenge 2: rewilding embraces uncertainty and longer timescales

Rewilding as a concept embraces uncertainty of outcomes and complexity of landscape dynamics. Trajectories of landscape dynamics driven by rewilding are difficult to predict and hydrological and sediment dynamics responses may be non-linear (e.g. Cerdà et al., 2018). For example, a fully hands-off approach requires acceptance of system disturbances such as species invasions as a natural process in ecosystem recovery (e.g. Tree, 2018). Timescales for change and associated benefits are nature-based, rather than engineering based, and may need to factor in temporal sequencing of rewilding (e.g. passive rewilding to develop appropriate habitat for later species reintroductions). Rewilding potentially involves long (and unknown) timescales, although responses can also be surprisingly rapid with significant change observed over decadal timescales (see Henshaw et al., 2021; Broughton et al., 2021). These principles and characteristics do not align neatly with the desire for rapid and predictable solutions to water resource management issues such as flood risk and low flow alleviation.

Cause for optimism may lie in the potential for landscapes to self-organise, underpinned by the fact that the re-establishment of natural processes is fundamental to the concept of rewilding. In some cases, change will occur over longer timescales and needs to account for the ‘complex response’ of earth surface systems to external drivers (Schumm, 1973). Here we may turn again to beaver where there is more of an evidence base. In incised streams in degraded landscapes, beaver dam development can initiate a process of adjustment that leads to a new dynamic equilibrium (Pollock et al, 2014). Initially, high stream powers may lead to dam blowouts at the event scale and a net erosional sediment regime (Brown et al., 2018). Over longer time scales, however, this process leads to channel widening, reduced stream power and the construction of more stable dams and ponds (Pollock et al., 2014) which vegetate, raise the water table and reconnect the river with its floodplain, switching the system to a net depositional regime (Pollock et al., 2014; Brown et al., 2018; Brazier et al., 2020).

3.3 Challenge 3: rewilding is (currently) geographically constrained

At present, rewilding projects tend to be dominated by charitable NGOs seeking to meet conservation and biodiversity goals, utilities companies seeking to benefit from more sustainable land management approaches, and private estates seeking to combine ecosystem recovery objectives with ecotourism and sustainable meat production (Sandom and Wynne-Jones, 2019; Rewilding Europe, 2021). This has led to the development of a distinctive geography of rewilding. For example, in the UK there has been a tendency towards afforestation in northern, upland environments and herbivore reintroductions to diversify vegetation development in southern, lowland environments (Sandom and Wynne-Jones, 2019). Delivery of rewilding at large scales is currently hampered by a lack of funding models. Despite considerable interest from sections of the agricultural community, many farmers have concerns over the financial viability of the approach for smaller producers given the fact many elements of rewilding practice are not covered by existing subsidy regimes. There is also notable apprehension about associated threats to farming culture and communities (e.g. Defra, 2021).

New funding approaches may provide opportunities to deliver rewilding and associated hydrological benefits over much larger scales and beyond the current emphasis on rural environments. For example, green infrastructure and sustainable drainage systems emphasise working with natural processes within heavily modified landscapes and there is much potential to translate and adapt rewilding principles and approaches to urban areas (e.g. Greater London Authority, 2023). China’s ‘Sponge Cities’ initiative is focused on creating an integrated approach to water management for urban areas, aiming to control 85% of annual runoff and attenuate both lower and high magnitude flood events (Lashford et al., 2019). The scheme is ambitious and funded through a combination of government funds and public-private partnerships with a goal for 80% of Chinese cities to use green infrastructure techniques by 2030 (Jiang et al., 2018). In the UK, the recent Agriculture Act (2020) enshrined the premise of “public money for public goods” in the UK’s farming subsidy system (Coe and Finlay, 2020). Basic Payments will be gradually phased out, and a new, three tier Environmental Land Management regime introduced to allow landowners to access payments for measures implemented at individual farm, local, and landscape scales (Defra, 2020; although at the time of writing the scheme is potentially facing revision). These schemes do not explicitly address rewilding, but there is scope to embed rewilding and NFM principles within these and similar initiatives. In addition, campaigns are now emerging that call for increased wildness of existing conservation spaces, for example National Parks in England (Rewilding Britain, 2021), which may contribute to extending the geographical reach of rewilding and its hydrological effects.

4. CONCLUSIONS AND RESEARCH AGENDA

Rewilding offers an unprecedented, radical and ambitious approach to environmental restoration at large scales with a range of potential effects on the water cycle. Like other NbS, including NFM, rewilding won’t provide a ‘solution’ to flooding or low flow problems by eliminating them, but could become part of a range of water resource management options that help to mitigate the impacts of hydrological extremes. Notwithstanding some key challenges associated with the novelty and uncertainty inherent in rewilding, and its current geographical extent, rewilding offers a mechanism for delivering multiple ecosystem services and benefits. Given the nature and scale of change rewilding can deliver to vegetation, soils and waterbodies, we argue that working with natural hydrological processes to mitigate the impacts of hydrological extremes should be considered a fundamental goal alongside other benefits such as biodiversity, carbon sequestration, water quality, rather than a ‘secondary’ benefit of rewilding. This would also support greater interdisciplinarity and reduce the silo-ing of expertise.

Certainly, rewilding is happening and is gaining momentum rapidly, providing diverse opportunities to monitor and evaluate the hydrological effects which to date have been largely overlooked. Below, we propose a research agenda to address the challenges we have identified. These challenges are inherently geographical and will require new interdisciplinary collaboration between ecologists, hydrologists, geographers, environmental economists and policy makers. Key future research priorities are:

1. An improved understanding of the trajectories of rewilding and styles of vegetation regeneration in different environmental settings. This includes understanding of legacy effects from previous land use and their influence on rewilding trajectories and outcomes.

2. Quantitative monitoring and modelling of the hydrological effects of rewilding to provide new understanding and prediction of hydrological changes at local and catchment scales and how these evolve over time, and evaluation of potential contributions to the mitigation of flood risk and low flow stresses.

3. Decision support tools to help landowners understand, visualise and evaluate different rewilding options to support access to funding and facilitate an extension of the geographical reach of rewilding projects.

4. Improved understanding of the social, economic and political factors influencing the future geographies of rewilding to inform both monitoring and the prediction of rewilding outcomes.

Funding Information

This work was supported by the UKRI Natural Environment Research Council/ Economic and Social Research Council (grant number NE/W007460/1) as part of the ‘Synthesising evidence for economics of biodiversity research programme’. The authors would also like to acknowledge the support of Queen Mary University of London’s HSS Collaboration Fund which enabled the establishment of research partnerships and the creation and analysis of data sets that inspired the ideas presented in this paper. Gemma Harvey was supported by The Leverhulme Trust via a Leverhulme Research Fellowship (grant number RF-2022-284\4).

Acknowledgments

We would like to thank the anonymous reviewers for their very helpful and constructive feedback on the manuscript.

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