TABLE Explainer

Rewilding and its implications for agriculture

September 2022

Walter Fraanje and Tara Garnett

TABLE Explainer series

UNIVERSITY OF OXFORD
SLU
WAGENINGEN UNIVERSITY & RESEARCH

Suggested citation

Fraanje, W., & Garnett, T. (2022). Rewilding and its implications for agriculture. TABLE Explainer Series. TABLE, University of Oxford, Swedish University of Agricultural Sciences and Wageningen University and Research. doi.org/10.56661/2aa26681

Written by

- Walter Fraanje, TABLE, Wageningen University & Research
- Tara Garnett, TABLE director, University of Oxford

This piece benefited from edits and comments from various TABLE team members including Helen Breewood, Trish Fisher and Wendy Jenkins.

Reviewed by

- Professor Emeritus Jozef Keulartz, Philosophy Group, Wageningen University and Research
- Professor Emeritus Kris van Koppen, Environmental Policy Group, Wageningen University and Research
- Professor Jamie Lorimer, School of Geography and the Environment, University of Oxford
- Rebecca Wrigley, Chief Executive, Rewilding Britain

We also had exchanges with another reviewer whose comments were very useful, but who wishes to remain anonymous.

Note that reviewing and advising do not constitute an endorsement, and the named reviewers should not be understood to agree with everything in the piece. Final editorial decisions, including any remaining inaccuracies and errors, are the sole responsibility of TABLE.

Funded by

- The Oxford Martin School
- The Swedish University of Agricultural Sciences
- Wageningen University and Research
- The Wellcome Trust through the Livestock, Environment and People (LEAP) project (grant number 205212/Z/16/Z)
- The Quadrature Climate Foundation

Cover

Cover picture by cocoparisienne via Pixabay.

To read more from the Explainer series, visit www.tabledebates.org/explainers.

TABLE

TABLE is a global platform for knowledge synthesis, for reflective, critical thinking and for inclusive dialogue on debates about the future of food.

TABLE is a collaboration between the University of Oxford, the Swedish University of Agricultural Sciences (SLU) and Wageningen University and Research (WUR)

For more information:

www.tabledebates.org/about

Contents

Introduction

The term 'rewilding' is gaining ground in discussions about nature conservation and the future of agricultural landscapes. Rewilding is based on the idea that as human societies have developed and expanded geographically, 'wild' landscapes have become fragmented and domesticated. The ambition of rewilding is to turn the tide: it aims to give land back to nature and change the management of ecosystems for them to become more resilient and autonomous. Ultimately, rewilders argue, this will contribute to the restoration of global biodiversity, may strengthen other ecosystem functions such as flood protection and carbon sequestration, and changes how humans can experience nature. In fostering these goals, rewilders often draw inspiration from the species and ecological processes that landscapes have lost throughout human history.

The concept of rewilding emerged in the 1990s from the field of conservation biology but has gained wider resonance in recent years, now finding support from a diverse group of stakeholders, including environmental activists, philanthropists, journalists, corporations, farmers, policy makers and private foundations, who sometimes interpret the term differently. Influenced by these actors, debate about rewilding has evolved from a focus on the reintroduction of extinct species or their relatives in large nature reserves to a wider discussion about the future of nature, agriculture and rural landscapes in the Anthropocene.

This explainer introduces the concept of rewilding. It compares different rewilding strategies, explores their relationship with agriculture, and discusses major areas of contestation.

1. What is rewilding?

1.1 Origin and meaning

Although rewilding has only recently captured public attention, the concept is several decades old. The term was introduced in the early 1990s by a group of North American conservation biologists including Michael Soulé and Reed Noss who developed the first rewilding strategy (the 3C approach, see box 1). This early work on rewilding presented some of the core principles and ideas that still resonate within the rewilding community. It also sparked controversy and some of the critiques that were raised then are still central to the rewilding debate today. It is important to note that rewilding is a heterogeneous and evolving movement. While rewilding is often criticised for views that are present in the work of its early champions, rewilders today do not always see their own approaches reflected in these discussions.

Box 1: The 3C approach

Soulé and Noss' strategy to rewild North American landscapes is foundational to later rewilding strategies (section 3) and is defined by three principles[1]:

- Creating large areas (say >100,000 ha) without human intervention (cores),
- establishing linkages between them (corridors) and
- introducing large carnivores such as wolves.

Two concepts – keystone species and the island biodiversity theory – underpin this '3C approach'.

Keystone species are species "whose influence on ecosystem functioning and diversity are disproportionate to their numerical abundance"[1] – in other words, species that are the foundation of a flourishing, biodiverse ecosystem. Large predators are an important group of keystone species, Soulé and Noss point out. Packs of wolves, for instance, can cause habitats to change and diversify by limiting populations of large grazers and by instigating 'fear zones' (areas, for instance close to water sources, that are heavily controlled by predators). A central principle for increasing biodiversity here is the idea of restoring top-down trophic interactions: the relations between prey and predators cascading through the food chain[1]. Non-predatory keystone species include beavers, elephants and cavity-excavating birds such as woodpeckers.

The island biodiversity theory[1] states that the richness of species on a given island is predicted by (1) the size of the island and (2) its distance from the mainland: the smaller and further from the mainland an island is, the less biodiverse it will be. Rewilding suggests that, throughout human history, 'wilderness' has shrunk into ever smaller 'islands'. Reversing this tendency requires the creation of large conservation areas (*cores*) and their connection by *corridors*[1]. These would maintain a high biodiversity in part by supporting genetically diverse populations of large predators (*carnivores*), which require large territories.

Soulé and Noss introduce rewilding as an idea in contrast with mainstream biodiversity conservation. Reflecting on past decades of biodiversity conservation in North America, they conclude that the conservation movement has both failed to confront the root causes of biodiversity loss and lost sight of the 'intrinsic' and 'spiritual' value of 'wilderness' (note that wilderness is a loaded and contested term – see section 1.3). Biodiversity loss in North America, they point out, has a long history that started with the arrival of the first humans at the end of the Pleistocene; North America has gradually lost most of its 'wilderness' and with it many of the species that made biodiversity thrive. To break this trend, they argue, it would be necessary for large segments of land in North America to be 'rewilded'.

Central to Soulé and Noss' rewilding vision is the principle of reintroducing species such as the wolf, which went extinct in large parts of North America. The idea here is that the loss of so-called 'keystone species' (see box 1) can have a large impact on the overall functioning of the ecosystem and result in substantial biodiversity losses. Their reintroduction, on the other hand, could lead biodiversity to self-restore. Soulé and Noss refer here to the case of Yellowstone National Park where the reintroduction of wolves is thought to have made the park more biodiverse[1]. Their ultimate ambition, however, is to reintroduce a wider range of large mammals that would help biodiversity regain the complexity it had during the *Pleistocene*.

The principle of reintroducing species has become a main characteristic of rewilding initiatives and builds upon a particular perspective on conservation that was pioneered by Soulé and Noss. Mainstream biodiversity conservation,

they argue, follows a compositionalist model of first mapping an area's species composition and then protecting a set of smaller 'hotspots' that together represent this biodiversity[1,7]. This approach reduces 'wilderness' to a set of target species and habitats that require protection. However, it overlooks the conditions and processes that need to be in place to sustain biodiversity in the long run. Rewilding, instead, embodies a functionalist approach to ecosystems[7]. It views them as dynamically evolving sets of interacting species that cover all kinds of functions such as grazing, predating and scavenging[1,2,7,8]. The (re)introduction of species with particular functions in this complex may change how the ecosystem functions and set it on a pathway of increased species richness, more resilience and reduced dependence on human management[9].

Rewilding covers an increasingly diverse range of context-specific strategies (section 2) that are characterised by this functionalist approach. Most of them combine intentional reintroductions of a few species with a subsequent hands-off attitude to the ecosystem. Many rewilders today, however, are critical of Soulé and Noss' focus on the Pleistocene as an ideal for today's landscapes. Their focus tends to be less on re-creating any particular historical baseline and more on how the functional complexity of current ecosystems could be enhanced to foster biodiversity as well as ecosystem services such as carbon sequestration or flood protection[10,11].

1.2 Controversy

Rewilding has sparked controversy, in particular over the idea of reintroducing large mammals and over its implications for rural and indigenous communities. In a 2005 article[12], several US conservation biologists (including Soulé) argued for the introduction of cheetahs, elephants and lions in North American landscapes on the grounds that they would act as functional analogues for similar species that went extinct at the end of the *Pleistocene*. Some advocates of species reintroductions go a step further, hoping to introduce not just functional analogues but – one day – the extinct species themselves. Ecologists at the Pleistocene Park in Siberia, for instance, aim to bring a genetically engineered version of the mammoth 'back' to today's tundra landscapes (see box 2).

Box 2: A note on de-extinction

The term de-extinction – the intention of recreating an extinct species – features regularly in discussions about rewilding. De-extinction encompasses back-breeding and genetic engineering[13].

Back breeding refers to deliberate selective breeding of animals in an attempt to restore traits they are thought to share with an extinct relative species. An example is Heck cattle, commonly used in European conservation grazing projects. This breed is the result of a back breeding programme to 'recreate' the aurochs (an extinct species of wild cattle that used to inhabit large parts of Asia, Europe and North Africa). Back breeding selects for traits different from conventional livestock breeding: instead of meat or milk production, for example, it prioritises colour, body shape, grazing behaviour and 'hardiness' (the ability to survive in tough conditions and without human intervention).

Genetic engineering is a more controversial approach to de-extinction, supported by some but not all rewilders. Here, the genome of a living species is edited to more closely resemble that of an extinct relative species. The result is not an exact copy of the extinct species but an animal with similar characteristics. Some expect living specimens of such species in the next few decades. Several research projects are currently pursuing this pathway, including one that aims to create a hybrid embryo with mammoth traits programmed into an Asian elephant. These projects will need to overcome legal challenges before any specimens are reintroduced[14].

Critics argue that reintroduction plans rely on oversimplified views of how such species will interact with their environment[6,15,16]. Reintroducing large mammals that went (locally) extinct millennia ago can cause human-wildlife conflicts (see box 3) and impact on ecosystems in very similar ways as so-called invasive species: they may wreak havoc and devastate existing populations of native species. For some rewilders these ecosystem-changing effects are precisely why they think the species should be reintroduced[1,17]. Other rewilders however are critical of reintroducing large carnivores and functional analogues of extinct species or else call for a careful assessment of the potential implications for ecosystem functioning.

Box 3: The impacts of reintroductions on humans and farming

A concern for farmers and rural communities is that the reintroduction of large (predatory) mammals in their local area can cause human-wildlife conflicts. Large predators might attack livestock or even humans while large grazers may damage crops and pastures[18,19]. Vice versa, populations of large mammals are affected by humans – for example through road kills or because they become semi-domesticated as a result of contact with humans[20-23]. Interactions between wildlife and livestock can also spread diseases such as African swine fever or rabies (see our chapter on the connections between infectious diseases in humans and livestock).

The likelihood of human-wildlife conflicts depends on many factors, one being the separation of wildlife from human society by fences or other structures. Human deaths by wildlife attacks are generally rare[24] and much less common than livestock predation or crop damage[25]. In a wolf-inhabited area, for instance, one is much more likely to be bitten by a domestic dog than by a wolf[26]. However small, these risks are nevertheless real and affect people's sense of safety[26].

The level of depredation of livestock by carnivores is very context dependent and often low in contexts where wild prey species are relatively abundant and pastures are fenced[23,27-30]. Livestock kills are sometimes falsely blamed on wolves when they were caused by domestic dogs[31-33]. That said, even when livestock kills occur infrequently, the impacts for farmers can be considerable and include harm from animal injury and stress.

Another main critique of rewilding is that it is predicated on the view that 'wilderness' is a place devoid of humans. Some critics see rewilding as continuing a long history of *eco-imperialist* and *colonialist* conservation activities. Triggered by conceptions of wilderness that exclude people, these often went hand-in-hand with the denigration and displacement of rural and indigenous communities. Others point out that even if rewilding would not give rise to new displacements, it might still be used to legitimise existing inequalities and undermines conservation agendas that centre on both social and ecological justice.

Critics here tend to refer to rewilding's preoccupation with historical baselines: a posited time point in the past that marks an ecosystem's 'original state'. Attempts at restoring nature to its original, 'pristine' state, they point out, generally ignore the fact that very few, if any, landscapes are unshaped by human presence. This includes those landscapes that are categorised as 'wild' today, many of which have gained their 'wild' character – at least in part – from how they have been managed by indigenous peoples.

Some rewilding initiatives have abandoned the notion of a historical baseline (because of their possible societal or ecological implications – see section 2.1.2). Various of these explicitly state that they view people as part of nature and seek to develop approaches that work for *both* nature *and* local communities[34,35].

1.3 Rewilding our imagination

For many in the rewilding movement, rewilding encompasses much more than just biodiversity conservation. Some argue that the concept is underpinned by a belief that humanity has gone too far in regulating nature and domesticating the planet. The desire to discipline and control our world, they point out, has not only caused landscapes to become predictable (the British writer and activist George Monbiot for instance speaks of 'ecological boredom'[36]) but extends its influence into how we live, think, feel and experience the world around us.

An important distinction here is that between '*wilderness*' and '*wildness*'. Rewilders such as Soulé and Noss define rewilding as being first and foremost about the protection of wilderness. Others, however, place more emphasis on an idea of *wildness*. Whereas *wilderness* is a physical state of a landscape (uninhabited, not affected by human interventions), *wildness* indicates a quality (someone or something being undisciplined and/or resisting control). The spiritual goal of returning 'wildness' to life is not limited to how we manage landscapes but extends into other domains[37] (it can for example be seen in the increasing popularity of microadventures, wild swimming and wild fermentation). Rewilders who centre on *wildness* rather than *wilderness* also tend to have less hardline views about the need for rewilded areas to be protected from human presence.

More generally, the value rewilders attach to *wildness* is evident in their emphasis on nature's power and its resilience to restore itself when humans stop trying to subject it to their wishes. They tend to be critical of mainstream conservation for assuming nature to be first and foremost vulnerable and in need of human protection because this, in so doing, risks creating a self-fulfilling prophecy: by constraining species and habitats to protect what is currently there, it undermines nature's power to restore itself.

2. Rewilding today

Rewilding has evolved beyond the 3C approach into a family of strategies[7,38] that vary by geographical context. The majority of current rewilding projects are in North America and Europe, but attention to rewilding has also recently spread to other parts of the world including South Africa[39,40] and China[41,42] (see box 4).

Commonly used concepts include Pleistocene rewilding, Holocene rewilding, trophic rewilding and passive rewilding. These are different, but overlapping, perspectives that have evolved over time. The former two (section 2.1) refer to different historical baseline scenarios that some rewilders aim to restore. Trophic and passive rewilding (2.2) do not indicate such an end goal but refer to mechanisms through which rewilding, as an open-ended process, could take place.

Box 4: Who is practising rewilding?

Originally an academic proposition, rewilding has recently attracted interest from activists, philanthropists, corporations, farmers and politicians who share the goal of returning land to nature. Despite much discussion *about* rewilding for restoring nature globally, its principles have so far only been implemented in a few places and on a fairly small scale[8].

Existing rewilding projects have so far mostly been initiated by the private sector, spearheaded by philanthropists and owners of large estates and private nature reserves. Examples include the UK's Knepp Wildland project which covers around 1,400 **hectares** (ha) of former farmland owned by a baronet and the Samara Private Game Reserve in South Africa which consists of 27,000 ha land owned by a philanthropist who bought the land from several livestock farmers.

NGOs such as Rewilding Europe tend not to buy land but rather work with private landowners and public conservation projects to achieve their rewilding vision. This often involves rewilding principles being applied to a segment of the project area rather than to the entire landscape.

The Oostvaardersplassen in the Netherlands, which covers around 6,000 ha of land reclaimed from the sea, is one of the few projects operated by public authorities. Other public conservation projects have integrated some rewilding principles (e.g. keystone species reintroductions) without adopting an overall rewilding agenda. Some of these 'rewilding' efforts predate current interest in rewilding. In Norway, for instance, the musk ox was reintroduced during the 1930s and 1940s in what is now the Dovrefjell National Park.

2.1 A question of baselines

The historical baseline concept plays an important role in the rewilding debate. A major difference between rewilding strategies lies in how they address the baseline question. While this might seem a purely theoretical matter for conservation ecologists, it gives rise to different ways of managing the landscape, and this in turn to very different species and a different relationship to other land uses including farming.

At around the time *Pleistocene* rewilding emerged in North America in the 1990s, conservation biologists in Europe developed similar ideas but focused on the Holocene (2.2.1). In recent years, some rewilders have abandoned explicit historical baselines in favour of more future-oriented approaches (2.1.2 and 2.2.2). The discussion about these baselines shows how rewilding can radically challenge but also align with existing priorities for both biodiversity conservation and rural development.

At a fundamental level, rewilding foregrounds the question of baselines in conservation: it challenges conventional conservation's preoccupation with protecting what biodiversity is currently there (1.1) and instead shifts the baseline either back to a distant past (2.1.1) or forward to the Anthropocene (2.1.2)[43].

2.1.1 Pleistocene and Holocene baselines

The geographical origins of *Pleistocene* and *Holocene* rewilding (see box 5) explain some of the differences between them. Perhaps the most pronounced difference is that *Pleistocene* rewilding (emerged in North America) revolves around the reintroduction of large *predators* whereas Holocene rewilding (developed in Europe) focuses on the reintroduction of large herbivores.

Box 5: Pleistocene and Holocene rewilding

Pleistocene and Holocene rewilding are two models that aspire to restore landscapes and their biodiversity to different points in time: the Pleistocene – the period lasting from 2.5 million years ago until about 11,700 years before today – or the Holocene – lasting from the end of the Pleistocene till today.

Pleistocene rewilding refers to perspectives that adopt the Pleistocene as the reference point for the rewilding of today's landscapes. Projects generally assume a large scale (say >100,000 ha) or aim to expand to this scale and are generally intended for geographical contexts with low population densities and little competition with agricultural land use (e.g. Siberia and parts of the US).

YouTube video 1: Pleistocene Park: Born to rewild. Currently covering around 2000 ha land, the Pleistocene Park in Siberia aims to recreate the steppes of the Pleistocene in large parts of the Arctic by introducing large herbivores. This approach would limit the release of carbon dioxide and methane from thawing permafrost (which is contested). The project is also controversial for its ambition to reintroduce the mammoth by genetic engineering.

Holocene rewilding takes as its baseline the period after the last ice age when agriculture started to take off and, as a result, the human population grew rapidly. It is heavily influenced by the ideas of the Dutch conservation biologist Frans Vera who argues[44] that in the absence of large-scale intensive land uses, European lowlands would not, as often thought, develop into a dense, closed-canopy forest, but rather into an open park-like landscape maintained by large populations of herbivores. While this perspective is contested[45], it has influenced several rewilding projects including the Knepp Wildland project in the UK and the Oostvaardersplassen in the Netherlands (Figure 1). Holocene rewilding projects typically cover a relatively small amount of land (~1,000-10,000 ha) and revolve around the introduction of large herbivores such as the Konik horse (a primitive horse species) and Heck cattle.

Figure 1 – Two examples of Holocene rewilding. On the left: Longhorn cattle at the Knepp Wildland estate (image by Tomline43 via Flickr). On the right: Heck cattle in the Oostvaardersplassen (image by Peter Galvin via Flickr).

A notable difference between these two contexts is that the average European landscape has – and has had for a long time – a much higher population density than the average North American landscape. Large predators have been extinct for centuries in most of Europe and their reintroduction can be difficult, for example because typical conservation areas are much smaller than the territories required by such animals, resulting in a higher risk of human-wildlife conflicts than in North America.

In addition, most landscapes in Europe have long been intensively cultivated. Understandings of what European landscapes *should* look like and which species should be conserved are strongly influenced by how these landscapes have evolved under human influence. For instance, there is a long history in Europe of farmland bird conservation, mainly based on preventing human-made landscapes, such as extensively managed pastures and heathland, from either turning into forests or being lost to more intensive land uses. European rewilders' focus on large grazers aligns to a great extent with ambitions to preserve these human-made landscapes and associated species[46,47]. North American rewilders, on the other hand, call for large predator reintroductions in contexts where large herbivores are sometimes considered to inhibit tree growth and thereby habitat diversification[1,48].

2.1.2 Anthropocene rewilding

Various recent rewilding perspectives consider how humans and wildlife could live together in new ways and in new landscapes during the *Anthropocene*[49]. These '*Anthropocene rewilding*' perspectives criticise conservation for its 'backward looking' attitude and see rewilding as, first and foremost, a future-oriented endeavour. Their criticisms consist of two main areas:

First, critics raise ecological and historical questions: Which period counts as 'original' and why? How do we know what nature looked like before humans arrived? Does it matter that any act of 'restoration' is itself a human intervention? The US science writer Emma Marris, for example, points out that attempts at restoring ecosystems to a past state often ruin new forms of nature that can be valuable in their own right[50]. Marris, who has written critically about rewilding but whose books are also a source of inspiration for today's rewilding community, emphasises that ideas about what a landscape 'originally' looked like tend to go hand-in-hand with strong, dogmatic views about which species, ecosystems or landscape features are worth preserving and which are not. This is for example visible in the common tendency to classify species in desirable 'native species' and inferior 'invasive species' (with the latter often being weed out to prevent them from 'crowding out' the former)[50].

Second, critics of historical baselines in rewilding mention the socio-political implications of restoring nature to a pre-human baseline. The desire to restore such baselines, they argue, tends to be predicated on the flawed and romanticised ideal of 'pristine wilderness'. Ostensibly 'pristine' landscapes, however, have generally been managed by local communities for centuries or longer. Historically, the objective of preserving wilderness has led to evictions and the erasure of (indigenous) peoples' histories from their ancestral lands[51]. The concern here is that rewilding (or at least its pre-human baseline variants) revives the exact principles and assumptions that the conservation movement needs to renounce to confront its history of elitism, colonialism and eco-imperialism[7,51–53].

The critique on baselines has caused the vocabulary of the rewilding debate to change: *Pleistocene* and *Holocene* rewilding have now by and large made place for concepts such as trophic and passive rewilding (2.2) that do not prescribe a desired baseline scenario. There are, however, important differences between future-oriented *Anthropocene* rewilding initiatives: some of them endorse a 'people inclusive' perspective that seeks, in the words of their proponents, *pragmatic* win-wins for nature and local communities[54,55]. This part of the rewilding movement tends to advocate for a patchwork approach where rewilding principles are applied in different ways and at different scales depending on the context. Others, however, see ecological merit in the creation of 'novel ecosystems'[43,56] but stick to the goal of establishing large areas that are (largely) inaccessible to humans. Finally, while *Anthropocene* rewilding abandons the ideal of a baseline scenario, this does not mean that it disregards 'history' altogether. Initiatives may, for example, be found to restore the course of a river or to reintroduce a species that went locally extinct but without the overarching objective of resurrecting ecosystems of the past.

2.2 Trophic and passive rewilding: two different perspectives

Two main approaches to rewilding today are *trophic rewilding* and *passive rewilding*:

Trophic rewilding draws heavily on the original 3C approach but does not target a particular historical baseline[2,57,58] and is silent on the question of scale. Fundamentally, it is defined by the principle of restoring trophic interactions. North American rewilding strategies tend to focus on *top-down* trophic interactions (i.e. the influence of large carnivores cascading through the food chain), whereas European strategies generally adopt a *bottom-up* perspective (i.e. nutrient availability at lower trophic levels such as that of plants influencing population sizes at the level of herbivores and above)[43]. While the North American focus on large carnivores and European focus on large herbivores might seem contradictory, both are predicated on the restoration of trophic interactions and can be seen as synergetic[43]. In focusing on restoring ecosystems' trophic complexity, trophic rewilding encompasses all forms of rewilding that involve reintroductions (including *Pleistocene* and *Holocene* rewilding)[8,59].

Reintroductions are a deliberate human intervention, often with lasting impacts on the ecosystem. In trophic rewilding, reintroductions tend to be accompanied by other interventions such as fencing, which, although controversial, are in some cases a legal requirement[8,60–62]. So far, most trophic rewilding initiatives are based in Europe where, typically, they take place within a patchwork of other land uses and in regions with a high population density. Fencing here reduces the risk of road kills and human-wildlife conflicts[60,63]. These sites are generally small (1,000-10,000 ha) compared to the original 3C approach's vision of interconnected cores. Some rewilding projects such as the Oostvaardersplassen in the Netherlands have been criticised on animal welfare grounds for 'trapping' large herbivore populations in a small area where natural feed is scarce[64]. Other commentators of the Oostvaardersplassen approach, however, point out that the ethical questions here are complex as the reintroduced grazers blur the boundaries between 'wild' and 'domesticated' animals[65]. Opponents express little concern over the fate of 'wild animals' (who often live under a welfare-limiting regime of 'proactive culling'), but seem to impose welfare standards for livestock and companion animals to the de-domesticated/semi-wild animals in the Oostvaardersplassen[65].

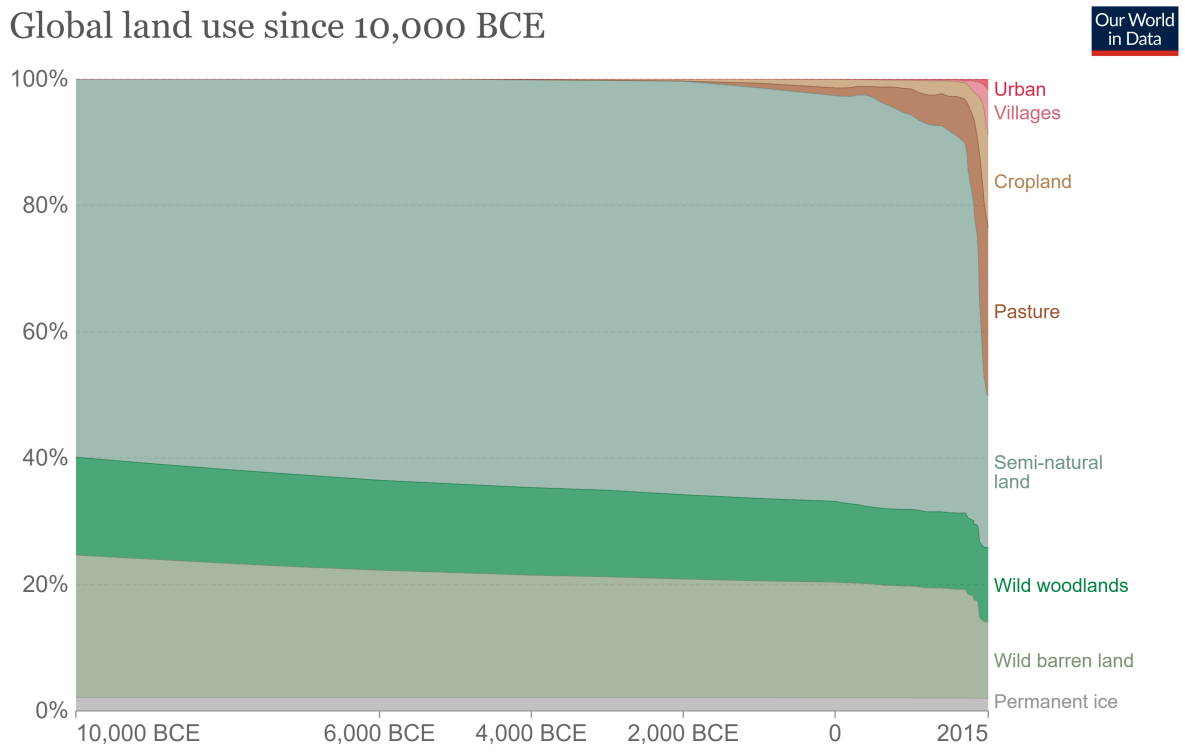
Sometimes trophic rewilding happens without active reintroductions[59]. Examples of this include the spontaneous

comeback of the beaver in the US and of the wolf in Europe. There is some overlap here between trophic rewilding and passive rewilding.

Passive rewilding is the spontaneous rewilding of ecosystems when land is left to its own devices[57,66]. It can be applied intentionally, but the concept also includes cases when (agricultural) land is abandoned. Arguably, as a result of farmland abandonment in Eastern Europe and some other world regions[67–69], unintentional passive rewilding currently covers far more land than do other forms of rewilding. Passive rewilding involves no or very little human intervention (e.g. sometimes fences are *removed* rather than *installed*) and does not specify an explicitly desired historical baseline scenario to which the landscape should revert or include deliberate reintroductions of keystone species. Intentional passive rewilding typically revolves around the understanding that processes such as globalisation, trade, climate change and land use change have altered ecosystems irreversibly. Rather than eradicating 'invasive species', passive rewilders tend to view that their place in these 'novel ecosystems' should be accepted and valued[43].

3. How does all this relate to agriculture?

Rewilding projects tend to take place either on farmland or on land dedicated to forestry or nature conservation. If rewilding were to scale up, much of its increased land cover may come from (abandoned) farmland. Agriculture is the greatest user of land in the world: to rewild these lands, whether by seeking to restore them to some past state or to allow them to evolve into some new state of wildness, would require a significant share of agricultural land being taken out of production or at least be used in a very different way (see figure 2).



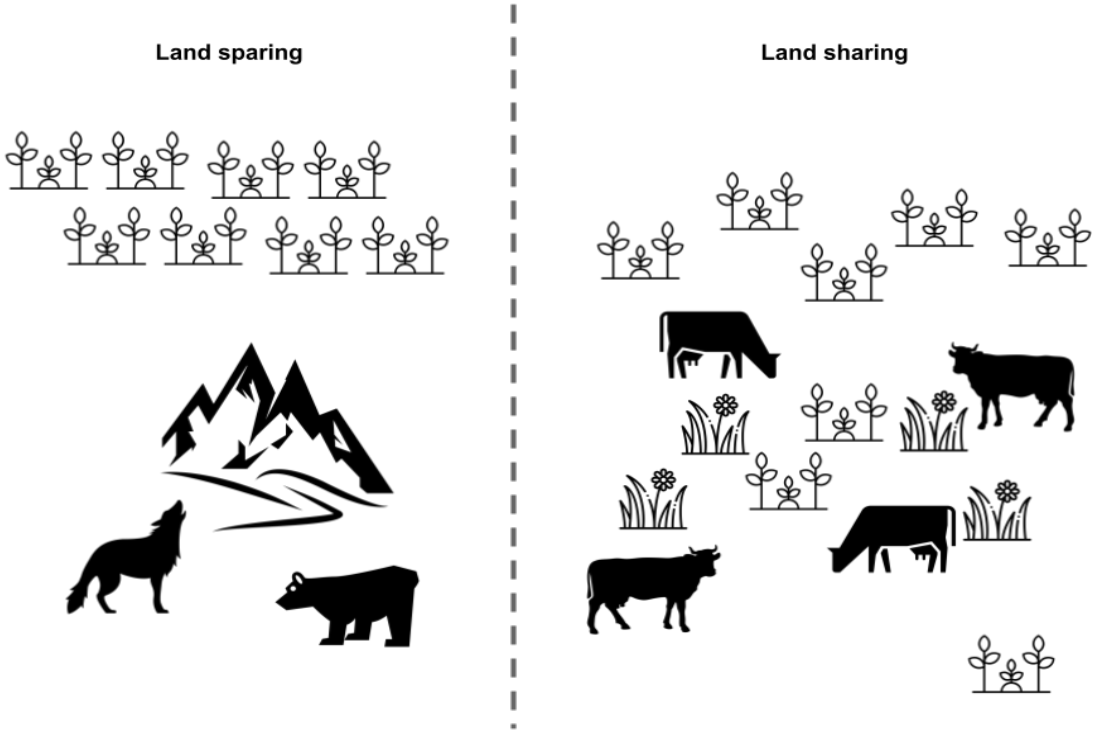
Source: Ellis, E. C., Beusen, A. H., & Goldewijk, K. K. (2020). Anthropogenic Biomes: 10,000 BCE to 2015 CE.

Figure 2: Global land use since 10,000 BC. Figure by Our World in Data based on data from Ellis, E.C., Beusen, AH., & Goldewijk, K.K. (2020)[70].

There is strong opposition to the idea of rewilding from some farming communities, based on the assumption that rewilding requires a substantial area of agricultural land to be taken out of production. However, this is not what all rewilders argue for.

Two differing perspectives seem to be emerging within the rewilding movement: The first is a more radical form of rewilding that aims to create a large network of protected areas isolated from society and which tends to find itself in tension with current agricultural landscapes. The second is more conciliatory and seeks to foster rewilding goals wherever possible and in balance with other socio-economic priorities including farming.

The radical form particularly resonates with (*Pleistocene*) rewilding strategies that call for the reintroduction of large predators and the creation of large 'core' areas for nature that are inaccessible for humans. From an overall land use perspective, this form of rewilding goes hand-in-hand with the principle of land sparing (see figure 3 and our explainer on the land sparing-sharing continuum). The idea here is to free up a maximum amount of land for nature by shrinking food production's land use through intensifying agricultural production.



Icons from the Noun Project: Agriculture by sam maulidna, Wolf by Bakunetsu Kaito, Bear by yandi kiem lie, Cow by Laymik, Cow by Laymik, Cow by Alena Artemova, Mountain by Vectors Market, and Grass and Flower by KP Arts.

Figure 3: A schematic representation of what land sparing and land sharing approaches to rewilding could look like. Figure by TABLE using icons from the Noun Project.

The second perspective calls for a mosaic of approaches. In some areas, it encourages the creation of larger core areas including the reintroduction of large carnivores. Proponents of this approach have for example advocated for the return of diverse woodlands on deer hunting estates in Scotland combined with the reintroduction of the lynx and a (partial) transition from livestock production on marginal lands to arable production on a smaller area of land (see YouTube video 2). However, they also tend to emphasise the need for such initiatives to find the support of local communities[71]. In more densely populated areas or existing arable farming landscapes, rewilding principles might be applied at much smaller scales and in synergy with farming. An example is the Knepp Wildland Project in the UK: An arable farm turned into a nature conservation project that still produces some (albeit very limited) agricultural output through the culling of the hardy cattle that were introduced to manage the landscape.

YouTube video 2: A video by Rewilding Britain showing what the rewilding of an upland valley in the UK could look like and which shows a transition from sheep farming to arable farming at a smaller scale.

These conciliatory approaches have found support among some farmer groups. They tend to promote the view that farmers can be both producers of food and caretakers of the natural environment. This in essence aligns with a land sharing model for landscapes based on the principle of *integrating* agricultural production and nature conservation on the same piece of land (see figure 3).

This part of the rewilding movement finds itself aligned with the regenerative farming and agroecology movements (see our interactive visual which explores the similarities and differences between the agroecology and regenerative movement). This is not only the result of their synergistic approach to farming and rewilding, but also because of more fundamental similarities between rewilding (both its conciliatory and radical flavours) and these movements. First, rewilding shares the prefix 're' with regenerative farming (as well as with 'reforestation' and 'ecological restoration'). Both contain the aspiration to return some of the species, ecological processes, or landscape features that were lost in the development of intensive (agricultural) land uses. Second, rewilding's principle of ecosystem restoration resonates with agroecology and regenerative agriculture's emphasis on 'healthy' soils and of 'working with' nature. Each of these movements promotes the idea that certain functions of soil, or ecosystems can and should be restored by changing our management of the land from merely constraining species to 'using life to manage life'[37]. This vision is visible both in rewilding's focus on keystone species and agroecology and regenerative agriculture's emphasis on soil microbes, fungi and root systems[72–75]. Those approaches are distinct from ones that aim to control ecosystems through repression alone (e.g. by culling deer or chemical pest control). A further similarity between regenerative agriculture and some versions of rewilding lies in the role they see for large herbivores in managing the landscape[76].

Whether rewilding requires an existing landscape to change significantly does not necessarily follow from how radical the chosen strategy is. For example, the implementation of a radical strategy may require very little to change in the case of an existing 'fortress conservation' project (a project built on the belief that the protection of nature needs to happen in isolation of people). On the other hand, the implementation of a conciliatory strategy could lead a landscape that is dominated by agricultural monocultures to change drastically. Depending on the strategy adopted, rewilding can accordingly be found to both challenge or align with many actors' pre-existing interests. Partly as a

result of this capacity to encompass a range of (sometimes conflicting) viewpoints, rewilding has found support from a diverse set of actors.

Most rewilding visions are positioned somewhere between the radical and conciliatory end points. Various of the more radical projects, for example, seek some involvement of local people (e.g. by hiring them as park managers or tourist guides). Some of the relatively conciliatory versions, on the other hand, call for integrated approaches to farming and rewilding in one place but for strong reductions in human presence and farming elsewhere. Monbiot, for instance, argues for a patchwork rewilding of 10% of Britain's terrestrial land, for an important part by removing sheep and deer from marginal lands in the uplands and by further reducing agricultural land use through farm-free production systems such as cellular agriculture[36,77]. This approach would have major implications for the UK's agricultural production, trade, diets and consumption. For Monbiot (and others), rewilding goes hand-in-hand with policies aimed at achieving substantial population-level dietary changes, especially major reductions in meat and dairy consumption[36,78].

4. Nature needs half

The radical perspective on rewilding finds strong support among some environmentalists and rich landowners who aim to create large refuges for threatened species. A leading and controversial example is the Nature Needs Half Campaign, which argues that to preserve 85% of the world's remaining biodiversity, a large network of protected areas should cover at least half of the Earth's surface by 2030[79,80]. (one of the pioneers of the island biodiversity theory) and championed by leading conservation biologists from the US including Noss[81], this half Earth perspective essentially applies the 3C approach globally.

Critics of the half Earth perspective have interpreted it as a proposal for separating society from nature on a global level. This, they point out, will have widespread negative consequences for people and in particular for the poorest, most exploited and most disenfranchised communities. They call instead for conservation approaches that see 'people as part of nature' and that foster 'socio-ecological justice'[82,83]. In addition to concerns that rewilding might provide a rationale for new displacements of rural and indigenous peoples, critics also fear that rewilding's relative 'blindness' to socio-political issues renders it incapable of identifying, challenging and ultimately reversing existing power dynamics. A case in point here is the current interest of rich elites in rewilding their private estates (in Scotland this process has been dubbed the 'rise of the Green Lairds'[84] – see also billionaire-funded initiatives elsewhere such as Rewilding Argentina)[85]. Local communities may have no say in such processes and positive narratives about rewilding's implications for nature might 'greenwash' the structural inequalities underlying land ownership models[83]. That said, the half Earth movement is heterogeneous and many of its members hold the view that actions to safeguard the world's biodiversity can and should pursue social justice at the same time (see e.g. the half-Earth project's statement on justice and inclusion).

Underlying this discussion are different analyses of issues and root causes. Coming as they do from a background in conservation biology, some rewilders and half Earth advocates understand the problem to be a loss of 'wilderness' and the species it sustains, which is fundamentally driven by the expansion of human societies and their demands. Critics coming from a social justice perspective see the ecological crisis as inextricably linked to the social problems we face as a species, since both ultimately originate from structural inequalities and an economy predicated on perpetual growth. The debate between these two groups should nevertheless not be reduced to a mere 'population growth versus overconsumption' debate. Both groups emphasize the importance of reducing resource-intensive lifestyles, but the latter group has a stronger and more explicit awareness of the unequal global power dynamics that underlie the issue and takes a more explicitly political approach. For example, parts of both groups are aligned in their view that global reductions in intensive livestock production and associated consumption of animal-based foods could help free up substantial areas of land for nature.

It is unlikely that the critique that rewilding reinforces existing power relations applies equally across all strategies and projects. Some of the more 'human-inclusive' rewilding initiatives explicitly aim for a more democratic approach. The Court Farm initiative in Dorset, for example, was enabled by a loan from a philanthropist but is operated by a local conservation charity that involves local communities in the decision making. More generally, versions of rewilding that lie at the land-sharing end of the spectrum find themselves aligned with agroecological approaches that emphasise the importance of social and ecological justice.

5. Different futures for nature

The premise of rewilding is that it will free up land for nature and that its overall impact on biodiversity will be positive. Very little research has studied this claim empirically – in part because there are still few practical examples of rewilding[8]. While rewilding is likely to mean 'more space for more species', the various strategies and visions for agriculture they relate to can result in different futures for nature and biodiversity.

The application of more radical or conciliatory rewilding approaches can have important implications for what a landscape will look like and the species that will inhabit it. Such differences include the possible presence of agriculture (or other land uses) in the landscape, the elimination of 'invasive species' (likely in, say, *Holocene* or *Pleistocene* rewilding but unlikely in passive rewilding) and the extent to which large herbivore populations, which affect tree growth, are present.

The rewilding movement encompasses a diversity of views on the future for landscapes. Perspectives here are not only influenced by ecological considerations but also by a combination of current land use patterns and pre-existing ideal conceptions of nature, rooted in culture and history. Finding their origins in *Pleistocene* rewilding, the more radical rewilding perspectives tend to echo the ideal of sublime, desolate wilderness that has influenced US culture through the work of writers such as Henry David Thoreau and John Muir[86,87]. These perspectives have found the support of a range of wealthy elites both in North America and elsewhere (e.g. South Africa, Argentina or Scotland) that aim to rewild their private estates with limited involvement of local communities. Conciliatory rewilding perspectives which seek synergies with agroecological and regenerative farming approaches resonate with visions of *pastoral Arcadia* and the Biblical garden of Eden, in which humans and nature harmoniously coexist[86-89]. These approaches have predominantly appeared in more densely populated contexts in Europe where rewilding takes place at a smaller scale and amidst competing land uses.

In terms of rewilding's ecological merits, the premise is that keystone species reintroductions will lead to more diverse habitats and species. Many rewilders, however, agree that this requires a context-specific approach where species are not introduced blindly but instead, their influence on the landscape, habitat formation and populations of current and potentially new species is considered[9]. In some cases, rewilding initiatives can lead to a loss of particular species in the landscape (and are met with opposition from conservationists who want to protect such species). In existing conservation areas, rewilding might result in increases in some species and reductions in others. For example, a few studies have found that introducing large herbivores to a nature reserve increases plant diversity but reduces arthropod diversity[90,91]. Another possibility is that a rewilding project's initial biodiversity successes (e.g. the return of some target bird species) may be temporary[92]. For example, a build-up of phosphorus fertiliser in abandoned farmland can cause the landscape to become gradually dominated by a few plant species (e.g. *juncus effusus*)[93-96].

On a landscape level, the extent to which rewilding takes place amidst human land uses may influence which species will flourish. Research on the effects of land-sparing and land-sharing approaches on biodiversity has shown that land-sparing landscapes generally support a greater diversity of specialist species, which can thrive only in specific habitats, whereas land-sharing landscapes tend to support mostly generalist species that can live in many habitat types[97,98]. This finding is important because most of the world's threatened species are specialists (see our explainer about the land sparing-sharing continuum). A caveat here is that agricultural lands, depending on how they are managed, can constitute an important habitat area for some specialist species. Wetland species such as the Black-

tailed Godwit, for example, have a preference for semi-flooded, herb-rich grasslands that are minimally grazed during their nesting season[99,100].

If rewilding were to be applied globally, which strategy dominates and the extent to which rewilding leans towards land sparing or sharing could have real consequences for the kinds of biodiversity that will flourish and for which species the world may lose.

6. Conclusions

Rewilding encompasses a range of strategies that share the goals of creating more space for nature and allowing it to restore 'autonomously'. Most of them centre on the notion of 'keystone species', whose reintroduction would return a full range of ecological functions to the landscape.

In recent years, rewilding has drawn the interest and support of diverse stakeholders, particularly from North America and Europe. While rewilding has evolved differently in these regions, the global rewilding movement is united in its goal to stop global biodiversity loss and kickstart its restoration. Shared among them is also a desire to create a 'wilder' Earth where humans will be able to experience nature – and more diverse natures – more frequently and in new, more diverse ways.

If rewilding were to scale up, this would have major implications for how rural landscapes develop. The exact consequences for nature, agriculture and rural populations would, however, differ according to which of the various rewilding strategies dominates within a given context.

Rewilding strategies differ in their position on agriculture. Radical perspectives (including *Pleistocene* rewilding) broadly align with principles of land sparing and associated agricultural intensification. They find themselves in partial tension with agroecology and regenerative farming agendas. Strategies that are more accommodating of human presence find themselves aligned with agroecological and regenerative farming practices.

Originating as it does in the field of conservation biology, rewilding has hitherto lacked a clear socio-economic focus or agenda. Critics question rewilding's implications for rural populations and indigenous peoples, given some rewilders' preoccupation with 'pristine wilderness'. Pleistocene rewilding and the half-Earth perspective are, in particular, criticised for advocating a separation between nature and human land uses. These more radical approaches to rewilding have found most support among wealthy landowners who operate large nature reserves in relatively sparsely populated areas (e.g. North America, South Africa, Argentina or parts of Scotland). More pragmatic forms of rewilding have emerged in more densely populated areas in Europe. These tend to seek synergies between rewilding and rural development and find themselves largely aligned with the agroecology and regenerative farming movements. These latter strategies can give rise to landscapes that contain more generalist species and provide less habitat to the world's most fragile species.

Go to contents

Glossary

Agricultural intensification

Agricultural intensification is the process of increasing the inputs of agricultural resources (e.g. seeds, labour, fertilisers, pesticides, technologies, knowledge) to increase the level of yield per unit of farmland or pasture. Agricultural intensification is not always clearly or consistently defined and is often confused with the term intensive agriculture. Unlike intensive agriculture, which could be seen as a specific system of agronomy, agricultural intensification is a general process that can apply, in principle, to any type of agricultural production. Examples of agricultural intensification may range from using new pesticides in intensive agriculture to intensifying the use of indigenous and context-specific knowledge in local farming practices. Although agricultural intensification can take many forms, it always involves the intensification of some types of agricultural input with a view to increase levels of yields.

Agricultural monoculture

A form of crop farming that is based on the growing of a single crop type on a field at a given point in time. Agricultural monocultures sometimes follow a rotational pattern where different crop types such as maize, wheat or soybeans are grown successively on the same field. The use of agricultural monocultures is typically based on the principle of economies of scale. The principle here is that the costs of inputs such as machinery, labour, fuel, herbicides, fertilisers and land per unit of output (kg yield) can be kept relatively low if the diversity of crops that are grown in an agricultural landscape is minimised. Agricultural monocultures are controversial within the environmental movement. Amongst other things their efficiency is debated and critics point out that the practice of agricultural monoculture can lead to externalities (i.e. costs such as biodiversity loss, water pollution or a lack of resiliency that are not reflected in the final cost of the product) and also for the most part goes hand-in-hand with ongoing corporate consolidation in the food system.

Anthropocene

The Anthropocene is the proposed (and, so far, unofficial) name for a new and current geological epoch distinguished by humanity's significant impacts on the planet's physical, chemical and biological systems, including climate and ecosystems. The exact start date and definition of the Anthropocene remain debated.

Agroecology

Agroecology is commonly understood as a science, a practice and a movement. As a science, it uses principles from the field of ecology to study the interactions between organisms in agroecosystems. It is often associated with transdisciplinary and action-oriented research, and the study of the entire food system. As a practice, agroecology combines indigenous and traditional knowledge, and scientific research, to generate productive, sustainable and resilient farming systems with minimal external inputs. This is achieved by optimizing processes and interactions occurring within agroecosystems, for example through crop rotations, cover crops, polycultures, crop-livestock integration, agroforestry and minimal tillage. It is generally associated with smallholder farming, and focuses on the production of nutritious food suitable for personal consumption and local markets. As a movement, agroecology seeks to address power imbalances within the food system, and generate a more just and equitable food system based on the principles of food sovereignty.

Arthropod

Arthropods are invertebrate animals such as a spiders, shrimp or beetles that have an exoskeleton, a segmented body and paired jointed appendages (paired wings, legs or antennae).

Back breeding

Back breeding is an approach to livestock breeding and part of a family of de-extinction practices. In back-breeding

programs, specimens, for example of certain domestic cattle breeds, are selected for breeding based on traits they are thought to share with an extinct ancestor species. This approach differs from conventional livestock breeding in that it tends to use other breeds and selects for a wider range of traits other than, say, meat or dairy yield. Sometimes, back-breeding projects deliberately avoid traits (such as aggressiveness) even when these are thought to have been present in the extinct species. Depending on when the species went extinct, it can be difficult to trace back its characteristics. Back breeding initiatives tend to rely on a combination of excavations and historical descriptions or depictions (cave drawings or paintings) of the species concerned. Sometimes these projects are based on idealised understandings of the species and do not consider the variety of traits that may have been present among different individuals.

Biodiversity

Biodiversity refers in the broadest sense to the variety and variability of living organisms in a particular area, or on earth in general. More specifically, the concept is used to denote different aspects of the variety and variability of life, e.g. the number of species in an area (species richness) or the size of species' populations (species abundance). Biodiversity is measured in different ways and at various scales from the genetic through to the landscape level.

Biodiversity conservation

Biodiversity conservation refers to all human activity aimed at the preservation of both the variety and variability of living organisms in a particular area of concern, or on earth in general. People value different aspects of biodiversity in different ways, and can have different priorities in biodiversity conservation e.g. to protect an endemic species or a species that supports an ecological process important to human wellbeing such as pollination.

Carbon sequestration

Carbon sequestration is any process by which carbon dioxide is removed from the atmosphere and stored elsewhere, whether by biological or technological means. There are two main types of carbon sequestration, terrestrial (carbon plants and soils), and geologic (carbon stored in rock formations) . One classic example of carbon sequestration is reforestation.

Cellular agriculture

Cellular agriculture refers to the production of agricultural products (foods or food ingredients as well as fuel or fibre) using cell cultures. Cell-based meat is a well-known example of cellular agriculture.

Conservation biology

Often described as a mission-driven discipline, conservation biology is a field of study concerned with the protection and maintenance of the earth's biodiversity. Research in conservation biology draws on other disciplines including ecology, biology and the social sciences and humanities.

De-extinction

De-extinction refers to the use of back breeding, cloning or genetic engineering to bring an extinct species 'back to life' or develop a species that is similar to it in terms of, for example, appearance and behaviour. The ambition of de-extinction initiatives is often for these species to be reintroduced and for them to contribute to the rewilding of landscapes.

Eco-imperialism

Eco-imperialism has been defined in various ways but is often used to refer to a situation where actors (e.g. people, communities, organisations or governments) that are perceived as powerful impose their ecological rationalities and actions, objectives or policies on other actors. A historical example of eco-imperialism can be seen in the development of national parks in the Americas by Western colonisers who (in many cases violently) expelled

indigenous communities from the land.

Ecological processes

All abiotic processes (processes related to non-living things such as warming from sunlight) and biotic processes (processes related to living things such as plant, animal and microbial activities) or combinations thereof that influence the state of an ecosystem.

Ecological restoration

Ecological restoration refers to the principle of restoring something, for example a landscape or an ecosystem, based on ecological principles, processes or methods. An example of this can be the restoration of an deforested area by allowing forest to re-emerge through various forest succession stages rather than planting a mixture of the plant species that used to be present before the area was deforested. Ecological restoration can take place as part of a rewilding strategy. Rewilding strategies, however, tend to come with more specific ideas about which species should be present or (re)introduced and a clear overall vision about particular processes in the ecosystem that should be encouraged.

Ecosystem restoration

Ecosystem restoration refers to the process of restoring aspects of an ecosystem that have been lost through for example the reintroduction of species or management practices to regain lost landscape features. The restoration of an ecosystem can be an outcome of rewilding. Not all rewilding strategies, however, aim to restore (aspects of) ecosystems that have been lost. Some rewilding strategies are more future oriented.

Farm-free production systems

Farm-free production systems refer to systems that generate food or types of fuel or fibre that are conventionally produced by agricultural systems but which are not produced on a farm. An example of a farm-free production system is the production of cellular meat in a bioreactor. While advocates of farm-free production systems tend to point towards potentially radical reductions in agricultural land use to produce a certain amount of food (or other products), farm-free production systems can be based on the use of ingredients (such as corn starch or soy protein) that are derived from more land-intensive production systems.

Fortress conservation

Fortress conservation is an approach to conservation that is based on the belief that goals for nature conservation are best achieved by the establishment of (large) nature reserves that are (largely) inaccessible to humans. Fortress conservation is controversial both for its assumption that the protection of biodiversity would be best served by creating isolated conservation areas and because it can go hand-in-hand with – and has historically done so – harms to rural and indigenous communities (e.g. displacements or even ethnic cleansing) who inhabit areas that are or were turned into fortress conservation projects.

Generalist species

A generalist species is a plant or animal species that is able to thrive in a large variety of environmental conditions, or that can live on a wide variety of foods. Members of the same generalist species can often be found at different parts of landscapes and in different regions of the world.

Heathland

Heathland is a shrubland habitat that is characterised by the presence of heather.

Hectare

Hectare (ha) is a unit of land equal to 10,000 square meters or 2.4711 acres.

Holocene

The Holocene is the current geological period and started about 11,700 years ago after a process of glacial retreat and a mass extinction of megafauna such as the sabre-toothed tiger, the mammoth and the woolly rhinoceros. The start of the Holocene roughly corresponds with the invention of agriculture and the start of a process of rapid growth and spread of the human species worldwide.

Holocene rewilding

Holocene rewilding is a rewilding strategy that takes the early to late Holocene (after the emergence of agriculture and before the industrial revolution) as its historical baseline for ecosystems. Whereas Pleistocene rewilding is associated primarily with the reintroduction of large carnivores, Holocene rewilding emphasises the role of large herbivores such as (ancient) cattle and horse species in managing the landscape. Holocene rewilding revolves around the wood-pasture hypothesis by the Dutch conservation biologist Frans Vera, which states that after the last ice age, European lowlands will have developed into semi-open pastures dotted with large solitary trees and small patches of trees and shrubs, kept open by large herbivores. This hypothesis is contested.

Invasive species

An invasive species is a species that is considered non-native or alien to a given ecosystem and whose introduction has caused, or is likely to cause, significant changes to the ecosystem. Invasive species can be seen as a subgroup of non-native species with characteristics that make them spread easily within their host ecosystem. Their impacts on ecosystems are often perceived as negative and harmful. For example, invasive species are typically described as crowding out populations of native species or harming them in other ways such as through predation. Some conservationists are critical of categorising species as native, non-native and invasive species. They point out that species have always travelled from one ecosystem to the other, in many cases enabled by the travels of humans. Some species that are perceived to be invasive in one area can also be near extinction in places where they are considered to be 'native' to.

Island biodiversity theory

The island biodiversity theory is a theory developed by North American conservation biologists in the 1960s that states that the richness of species on a given island is predicted by two factors: a) the size of the island and b) its distance from the mainland. The smaller and further from the mainland an island is, the less biodiverse it will be.

Keystone species

A keystone species is a species that has a disproportionate influence on the functioning of an ecosystem relative to its numerical abundance and in comparison with other species such that its loss or (re)introduction in an ecosystem can affect the ecosystem's overall functioning. Species such as the wolf, elephant or beaver are often considered to be keystone species but keystone species are not necessarily mammals. For example, woodpeckers or particular starfish species are sometimes included in this category.

Land sharing

Land sharing is the principle of integrating nature conservation approaches into agricultural production across a region. Its characteristics are that of low-yielding farmland with higher biodiversity, but with less land available for the sole purpose of nature conservation. Land sharing sits at one end of the two extremes of the land sparing-sharing continuum. It has in particular been criticised for leading to lower levels of biodiversity on a regional scale and for a tendency for generalist species to thrive at the expense of specialist or endemic species.

Land sparing

Land sparing is the principle of segregating land for nature conservation from land for food (or agricultural) production within a region. It consists of high-yielding farmland with relatively lower biodiversity, with the remaining land being spared for nature conservation. Land sparing sits at one end of the two extremes of the land sparing-sharing continuum. It has in particular been criticised for its (supposed) connection to environmentally unsustainable intensive agriculture and for undermining the food security of smallholder farmers and rural economies.

Marginal land

Marginal land is often defined as land that has little value for agricultural production because the difference between the costs of agricultural inputs (e.g. labour, machinery, agrochemicals) and the revenue that can be achieved from yields is small compared to what can be achieved on other land. Marginal land is sometimes defined in contrast with arable land, where marginal land is understood to be land that is unsuitable for crop production but still could be used for grazing by livestock. While the agricultural value of marginal land can be low, both its existing and potential value for biodiversity conservation can be high.

Native species

A native species is a species that is considered indigenous to a given ecosystem or region. A species is typically perceived to be a native species when it has been present in the ecosystem or region for a long time. This can be anything from a few centuries up to several millennia. Which species are seen as native or non-native depends on the historical baseline one adopts and is to some extent open for interpretation and debate.

Novel ecosystems

Novel ecosystems are ecosystems that as a result of human influences have changed to the extent that the biotic elements (living things such as animals, plants or bacteria) and abiotic elements (non-living things such as water, rocks and air) are almost entirely different from what they have been in a historical state of the ecosystem. Novel ecosystems are defined relative to a past state of the ecosystem and the role humans have had in changing it. While this means that what does and does not count as a novel ecosystem is context dependent and subject to interpretation, the concept is generally used to refer to ecosystems that have experienced substantial human-induced changes in recent history (say the past two centuries). Examples of ecosystems that are often considered as 'novel' are deforested primary forests and areas that have a very different species composition due to the introduction and spread of non-native species resulting from human activity such as intercontinental trade.

Passive rewilding

Passive rewilding refers to the spontaneous rewilding of ecosystems when land is left to its own devices. It can be applied intentionally, but the concept also includes cases when (agricultural) land is abandoned. Arguably, as a result of farmland abandonment in Eastern Europe and some other world regions, unintentional passive rewilding currently covers far more land than do other forms of rewilding. Passive rewilding involves no or very little human intervention and does not specify an explicitly desired historical baseline scenario to which the landscape should revert, or include deliberate reintroductions of keystone species.

Pleistocene

The geological period that lasted from roughly 2.5 million years ago until about 11,700 years ago. The Pleistocene ended with a mass extinction of large megafauna such as the mammoth and the woolly rhinoceros. Note that the exact role of humans in megafaunal extinction remains contentious.

Pleistocene rewilding

Pleistocene rewilding is a rewilding strategy that takes the Pleistocene (the period from roughly 2.5 million years ago

until about 11,700 years ago) as its historical baseline for ecosystems. While Pleistocene rewilders draw inspiration from the species and functional complexity of ecosystems during the Pleistocene, they do not necessarily aim to recreate the exact same ecosystems as existed during this period. Pleistocene rewilding is associated with the reintroduction of large carnivores such as the wolf. It has mainly been promoted in North America and has its origins in the 3C-approach: an approach to rewilding that calls for the establishment of large cores (nature conservation areas where human interference is minimised), corridors that allow wildlife to travel between core areas, and the reintroduction of large carnivores. Pleistocene rewilding is contested as – depending on the context – it could give rise to human-wildlife conflicts and has been criticised for being based on views and principles that could lead to the marginalisation and displacement of rural and indigenous communities.

Reforestation

Reforestation refers to the spontaneous or intentional return of trees in an area that has lost its forest cover either as a result of deforestation by humans or in other ways such as wildfire or drought.

Regenerative agriculture

Regenerative agriculture aims to generate farming systems that improve soil health, increase biodiversity and sequester carbon through the use of practices such as cover crops, crop rotations, minimal tillage, organic compost, agroforestry and crop-livestock integration. Many of these practices are also associated with organic farming and agroecology. Various certification schemes are being developed which will specify the processes and outcomes required for products to be classified as 'regenerative'

Reintroduced species

Reintroduced species are species that are introduced by humans into an ecosystem to replace a species of the same type that has gone (locally) extinct. A reintroduced species can either be of the same species type as the species that was lost or a related species with similar appearance and/or behaviour.

Rewilding

Rewilding is a broad concept that emerged in the 1990s in the field of conservation biology and which has evolved in recent years to encompass a range of visions on nature and the management of ecosystems. Rewilding revolves around the understanding that 'nature' has become marginalised throughout human history. The ambition of rewilding is to turn the tide: it aims to give land back to nature and change the management of ecosystems for them to become more resilient and autonomous. In doing so, rewilding aims to kickstart the restoration of global biodiversity and strengthen ecosystem functions such as flood protection and carbon sequestration. An important underlying objective for many rewilders is to create a 'wilder' Earth where humans will be able to experience nature more frequently and in new, more diverse ways. Common rewilding strategies include trophic rewilding (the restoration of complex trophic interactions between species kickstarted by the reintroduction of keystone species such as large carnivores or large herbivores) and passive rewilding (the spontaneous rewilding of ecosystems when land is left to its own devices). Rewilding is a contested term. Debate centers on the implications of rewilding for food production and for rural and indigenous communities. An important topic of discussion concerns the extent to which rewilding is compatible with farming and whether its large-scale adoption would require a substantial downscaling of agricultural land use. Further topics of debate include the goal of some rewilders to restore landscapes to a pre-human baseline (see Pleistocene and Holocene rewilding) and various proposals to reintroduce large carnivores (e.g. wolves and tigers) in places where these went extinct. While rewilders today do not always see their own approaches reflected in these discussions, critics of rewilding are in favour of alternative visions that seek to restore nature and biodiversity through approaches that they see to be more clearly based on the principle of social justice.

Selective breeding

Selective breeding refers to the deliberate human practice of choosing which plants or animals to breed together,

based on specific characteristics, in order to selectively enhance these characteristics (and their genetic basis) in their offspring.

Specialist species

A specialist species is a plant or animal species that is able to thrive in only a limited variety of environmental conditions, or that has a limited diet. Unlike endemic species, populations of the same specialist species may be present at different geographical locations around the world.

Trophic interactions

Trophic interactions refer to the feeding and nutrient exchange relationships between organisms. Examples of trophic interactions include predation, grazing and parasitism.

Trophic rewilding

Trophic rewilding is defined by the principle of restoring trophic interactions. These include predator-prey relationships in the food chain but also other processes such as scavenging or decaying that constitute nutrient flows in the ecosystem. Trophic rewilding aims for the diversification and increasing complexity of the web of such interactions. As such trophic rewilding is a broad concept that encompasses other rewilding strategies such as Pleistocene and Holocene rewilding. However, unlike these more specific strategies trophic rewilding does not seek to restore nature to a particular historical baseline and is silent on questions about scale.

References

1. Soulé, M. & Noss, R. Rewilding and biodiversity: complementary goals for continental conservation. Wild Earth 8, 18–28 (1998).

2. Svenning, J.-C. et al. Science for a wilder Anthropocene: Synthesis and future directions for trophic rewilding research. Proceedings of the National Academy of Sciences 113, 898–906 (2016).

3. van der Hoek, Y., Gaona, G. V., Ciach, M. & Martin, K. Global relationships between tree-cavity excavators and forest bird richness. Royal Society Open Science 7, 192177.

4. MacArthur, R. H. & Wilson, E. O. The Theory of Island Biogeography. (Princeton University Press, 2001).

5. Triantis, K. A. & Matthews, T. J. Biodiversity theory backed by island bird data. Nature 579, 36–37 (2020).

6. Keulartz, J. Rewilding. in Oxford Research Encyclopedia of Environmental Science (Oxford University Press, 2018). doi:10.1093/acrefore/9780199389414.013.545.

7. Lorimer, J. et al. Rewilding: Science, Practice, and Politics. Annual Review of Environment and Resources 40, 39–62 (2015).

8. Bakker, E. S. & Svenning, J.-C. Trophic rewilding: impact on ecosystems under global change. Philosophical Transactions of the Royal Society B: Biological Sciences 373, 20170432 (2018).

9. Carver, S. et al. Guiding principles for rewilding. Conservation Biology n/a.

10. Cromsigt, J. P. G. M. et al. Trophic rewilding as a climate change mitigation strategy? Philosophical Transactions of the Royal Society B: Biological Sciences 373, 20170440 (2018).

11. Thakur, M. P., Bakker, E. S., Veen, G. F. (Ciska) & Harvey, J. A. Climate Extremes, Rewilding, and the Role of Microhabitats. One Earth 2, 506–509 (2020).

12. Donlan, J. Re-wilding North America. Nature 436, 913–914 (2005).

13. Shapiro, B. Pathways to de-extinction: how close can we get to resurrection of an extinct species? Functional Ecology 31, 996–1002 (2017).

14. Wagner, N. et al. De-extinction, nomenclature, and the law. Science 356, 1016–1017 (2017).

15. Rubenstein, D. R., Rubenstein, D. I., Sherman, P. W. & Gavin, T. A. Pleistocene Park: Does re-wilding North America represent sound conservation for the 21st century? Biological Conservation 132, 232–238 (2006).

16. Oliveira-Santos, L. G. R. & Fernandez, F. A. S. Pleistocene Rewilding, Frankenstein Ecosystems, and an Alternative Conservation Agenda. Conservation Biology 24, 4–5 (2010).

17. Donlan, J. Re-wilding north America. Nature 436, 913–914 (2005).

18. Gordon, I. J. What is the Future for Wild, Large Herbivores in Human-Modified Agricultural Landscapes? wbio 15, 1–9 (2009).

19. Gross, E. M. et al. Seasonality, crop type and crop phenology influence crop damage by wildlife herbivores in Africa and Asia. Biodivers Conserv 27, 2029–2050 (2018).

20. Huber, Đ., Kusak, J., Frković, A., Gužvica, G. & Gomerčić, T. Causes of wolf mortality in Croatia in the period 1986-2001. Veterinarski arhiv 72, 131–139 (2002).

21. Lovari, S., Sforzi, A., Scala, C. & Fico, R. Mortality parameters of the wolf in Italy: does the wolf keep himself

from the door? Journal of Zoology 272, 117–124 (2007).

22. Murray, D. L. et al. Death from anthropogenic causes is partially compensatory in recovering wolf populations. Biological Conservation 143, 2514–2524 (2010).

23. Imbert, C. et al. Why do wolves eat livestock? Biological Conservation 195, 156–168 (2016).

24. Ritchie, H. & Roser, M. Causes of Death. Our World in Data (2018).

25. Dunham, K. M., Ghiurghi, A., Cumbi, R. & Urbano, F. Human–wildlife conflict in Mozambique: a national perspective, with emphasis on wildlife attacks on humans. Oryx 44, 185–193 (2010).

26. Linnell, J. et al. The fear of wolves: A review of wolf attacks on humans. (2002).

27. Meriggi, A. & Lovari, S. A Review of Wolf Predation in Southern Europe: Does the Wolf Prefer Wild Prey to Livestock? Journal of Applied Ecology 33, 1561–1571 (1996).

28. Mattioli, L. et al. Predation by wolves (Canis lupus) on roe deer (Capreolus capreolus) in north-eastern Apennine, Italy. Journal of Zoology 264, 249–258 (2004).

29. Gazzola, A., Capitani, C., Mattioli, L. & Apollonio, M. Livestock damage and wolf presence. Journal of Zoology 274, 261–269 (2008).

30. Theuerkauf, J. What Drives Wolves: Fear or Hunger? Humans, Diet, Climate and Wolf Activity Patterns. Ethology 115, 649–657 (2009).

31. Plumer, L., Talvi, T., Männil, P. & Saarma, U. Assessing the roles of wolves and dogs in livestock predation with suggestions for mitigating human–wildlife conflict and conservation of wolves. Conserv Genet 19, 665–672 (2018).

32. De wolf zoekt z'n plekje. issuu https://issuu.com/wageningenur/docs/ww2020_03_nl/s/11023181.

33. Caniglia, R., Fabbri, E., Mastrogiuseppe, L. & Randi, E. Who is who? Identification of livestock predators using forensic genetic approaches. Forensic Science International: Genetics 7, 397–404 (2013).

34. People and rewilding. Rewilding Britain https://www.rewildingbritain.org.uk/explore-rewilding/people-and-rewilding.

35. The people perspective. Rewilding Europe https://rewildingeurope.com/blog/the-people-perspective/ (2020).

36. Monbiot, G. Feral: Rewilding the land, the sea, and human life. (University of Chicago Press, 2014).

37. Lorimer, J. The Probiotic Planet: Using Life to Manage Life. vol. 59 (U of Minnesota Press, 2020).

38. Gammon, A. R. The Many Meanings of Rewilding: An Introduction and the Case for a Broad Conceptualisation. Environmental Values 27, 331–350 (2018).

39. Rewilding Africa. Peace Parks Foundation https://www.peaceparks.org/rewilding-africa/.

40. Conservation successes | Samara Private Game Reserve, South Africa. Samara Private Game Reserve https://www.samara.co.za/conservation/successes/.

41. Save China's Tigers - Rewilding. https://www.savechinastigers.org/rewilding.html.

42. Zhang, Y. et al. Reversing extinction in China's Père David's deer. Science 371, 685.2-686 (2021).

43. Keulartz, J. Future Directions for Conservation. environ values 25, 385–407 (2016).

44. Vera, F. W. M. Grazing Ecology and Forest History. (CABI publishing, 2000).

45. Birks, H. J. B. Mind the gap: how open were European primeval forests? Trends in Ecology & Evolution 20, 154–156 (2005).

46. Sundseth, K. & Creed, P. Natura 2000: protecting Europe's biodiversity. (European Commission, Directorate General for the Environment, 2008).

47. Navarro, L. M. & Pereira, H. M. Rewilding abandoned landscapes in Europe. in Rewilding European Landscapes 3–23 (Springer, Cham, 2015).

48. Creel, S. & Christianson, D. Wolf presence and increased willow consumption by Yellowstone elk: implications for trophic cascades. Ecology 90, 2454–2466 (2009).

49. Lorimer, J. Wildlife in the Anthropocene: conservation after nature. (U of Minnesota Press, 2015).

50. Marris, E. The Rambunctious Garden: Saving Nature in a Post-Wild World. 2011. New York: Bloomsbury USA (2013).

51. Ward, K. For wilderness or wildness? Decolonising rewilding. in Rewilding (eds. Pettorelli, N., Durant, S. M. & du Toit, J. T.) 34–54 (Cambridge University Press, 2019). doi:10.1017/9781108560962.003.

52. Agrawal, A. & Redford, K. Conservation and Displacement: An Overview. Conservation and Society 7, 1–10 (2009).

53. How We Can Eradicate Eco-Colonialism As Our Enchantment With Rewilding Widens. HOLLYROSE.ECO https://hollyrose.eco/2019/01/grounded-how-we-can-eradicate-eco/ (2019).

54. Rewilding Europe. Three-year strategic plan 2019-2021. (2019).

55. Rewilding: restoring our livelihoods and wellbeing alongside nature. Rewilding Britain https://www.rewildingbritain.org.uk/blog/rewilding-and-jobs-blog.

56. Klop-Toker, K., Clulow, S., Shuttleworth, C. & Hayward, M. W. Are novel ecosystems the only novelty of rewilding? Restoration Ecology 28, 1318–1320 (2020).

57. Pettorelli, N., Durant, S. M. & du Toit, J. T. Rewilding: a captivating, controversial, twenty-first-century concept to address ecological degradation in a changing world. in Rewilding (eds. Pettorelli, N., Durant, S. M. & du Toit, J. T.) 1–11 (Cambridge University Press, 2019). doi:10.1017/9781108560962.001.

58. Rubenstein, D. R. & Rubenstein, D. I. From Pleistocene to trophic rewilding: A wolf in sheep's clothing. PNAS 113, E1–E1 (2016).

59. Svenning, J.-C. & Faurby, S. Prehistoric and historic baselines for trophic rewilding in the Neotropics. Perspectives in Ecology and Conservation 15, 282–291 (2017).

60. Bull, J. W., Ejrnæs, R., Macdonald, D. W., Svenning, J.-C. & Sandom, C. J. Fences can support restoration in human-dominated ecosystems when rewilding with large predators. Restoration Ecology 27, 198–209 (2019).

61. Corlett, R. T. The Role of Rewilding in Landscape Design for Conservation. Curr Landscape Ecol Rep 1, 127–133 (2016).

62. Hayward, M. W. & Kerley, G. I. H. Fencing for conservation: Restriction of evolutionary potential or a riposte to threatening processes? Biological Conservation 142, 1–13 (2009).

63. Sweeney, O. F. et al. An Australian perspective on rewilding. Conservation Biology 33, 812–820 (2019).

64. Kopnina, H., Leadbeater, S. & Cryer, P. The golden rules of rewilding - examining the case of Oostvaardersplassen. Ecos - A Review of Conservation 40, (2019).

65. Keulartz, J. Philosophical Boundary Work for Wildlife Conservation. in A Guide to Field Philosophy (eds. Brister, E. & Frodeman, R.) 127–142 (Routledge, 2020). doi:10.4324/9781351169080-9.

66. Morel, L. et al. Passive rewilding may (also) restore phylogenetically rich and functionally resilient forest plant communities. Ecological Applications 30, e02007 (2020).

67. Benayas, J., Martins, A., Nicolau, J. & Schulz, J. J. Abandonment of agricultural land: An overview of drivers and consequences. CAB Reviews: Perspectives in Agriculture, Veterinary Science. Nutrition and Natural Resources 2, (2007).

68. Levers, C., Schneider, M., Prishchepov, A. V., Estel, S. & Kuemmerle, T. Spatial variation in determinants of agricultural land abandonment in Europe. Science of The Total Environment 644, 95–111 (2018).

69. Poore, J. A. Call for conservation: Abandoned pasture. Science 351, 132–132 (2016).

70. Ellis, E. C., Beusen, A. H. W. & Goldewijk, K. K. Anthropogenic Biomes: 10,000 BCE to 2015 CE. Land 9, 129 (2020).

71. Eurasian Lynx Position Statement. Rewilding Britain https://www.rewildingbritain.org.uk/news-and-views/policy-statements/eurasian-lynx-position-statement.

72. Cole, C. V., Elliott, E. T., Hunt, H. W. & Coleman, D. C. Trophic interactions in soils as they affect energy and nutrient dynamics. V. Phosphorus transformations. Microb Ecol 4, 381–387 (1977).

73. Lehmann, J., Bossio, D. A., Kögel-Knabner, I. & Rillig, M. C. The concept and future prospects of soil health. Nat Rev Earth Environ 1, 544–553 (2020).

74. Schreefel, L., Schulte, R. P. O., de Boer, I. J. M., Schrijver, A. P. & van Zanten, H. H. E. Regenerative agriculture – the soil is the base. Global Food Security 26, 100404 (2020).

75. Sherwood, S. & Uphoff, N. Soil health: research, practice and policy for a more regenerative agriculture. Applied Soil Ecology 15, 85–97 (2000).

76. Jepson, P. & Blythe, C. Rewilding: The Radical New Science of Ecological Recovery. (Icon Books, 2020).

77. Intelligence Squared. The Battle for the Countryside: Britain Should Rewild its Uplands.

78. Lab-grown food is about to destroy farming – and save the planet | George Monbiot. the Guardian http://www.theguardian.com/commentisfree/2020/jan/08/lab-grown-food-destroy-farming-save-planet (2020).

79. Wilson, E. O. Half-earth: our planet's fight for life. (WW Norton & Company, 2016).

80. Why 50%. Nature Needs Half https://natureneedshalf.org/why-50/.

81. Noss, R. F. et al. Bolder Thinking for Conservation. Conservation Biology 26, 1–4 (2012).

82. Büscher, B. et al. Half-Earth or Whole Earth? Radical ideas for conservation, and their implications. Oryx 51, 407–410 (2017).

83. Ellis, E. C. & Mehrabi, Z. Half Earth: promises, pitfalls, and prospects of dedicating Half of Earth's land to conservation. Current Opinion in Environmental Sustainability 38, 22–30 (2019).

84. Who Owns Scotland? The millionaires buying up the Highlands. Reuters.

85. The Guardian view on rewilding Scotland: an immodest proposal | Editorial. the Guardian http://www.theguardian.com/commentisfree/2019/mar/21/the-guardian-view-on-rewilding-scotland-an-immodest-proposal (2019).

86. Nash, R. F. Wilderness and the American mind. (Yale University Press, 1965).

87. Cronon, W. The trouble with wilderness: or, getting back to the wrong nature. Environmental history 1, 7–28 (1996).

88. Van Koppen, C. S. A. (Kris). Resource, Arcadia, Lifeworld. Nature Concepts in Environmental Sociology. Sociologia Ruralis 40, 300–318 (2000).

89. Drenthen, M. & Keulartz, J. Introduction. in Old World and New World Perspectives in Environmental Philosophy: Transatlantic Conversations (eds. Drenthen, M. & Keulartz, J.) 1–14 (Springer International Publishing, 2014). doi:10.1007/978-3-319-07683-6_1.

90. Klink, R. van. Of dwarves and giants: How large herbivores shape arthropod communities on salt marshes. (2014).

91. Klink, R. van, Plas, F. van der, Noordwijk, C. G. E. (Toos) van, WallisDeVries, M. F. & Olff, H. Effects of large herbivores on grassland arthropod diversity. Biological Reviews 90, 347–366 (2015).

92. Bijlsma, R. Atlas Contact Kerken van goud, dominees van hout. (Atlas Contact, 2021).

93. Smolders, A. J. P., Lucassen, E. C. H. E. T., Van Der Aalst, M., Lamers, L. P. M. & Roelofs, J. G. M. Decreasing the Abundance of Juncus effusus on Former Agricultural Lands with Noncalcareous Sandy Soils: Possible Effects of Liming and Soil Removal. Restoration Ecology 16, 240–248 (2008).

94. Lamers, L., Lucassen, E., Thomassen, H., Smolders, A. & Roelofs, J. Verpitrussing'bij natuurontwikkeling: voorkomen is beter dan genezen. De Levende Natuur 110, 43–46 (2009).

95. Agethen, S. & Knorr, K.-H. Juncus effusus mono-stands in restored cutover peat bogs – Analysis of litter quality, controls of anaerobic decomposition, and the risk of secondary carbon loss. Soil Biology and Biochemistry 117, 139–152 (2018).

96. Lamers, L. P. M. et al. Ecological restoration of rich fens in Europe and North America: from trial and error to an evidence-based approach. Biological Reviews 90, 182–203 (2015).

97. Phalan, B. T. What Have We Learned from the Land Sparing-sharing Model? Sustainability 10, 1760 (2018).

98. Feniuk, C., Balmford, A. & Green, R. E. Land sparing to make space for species dependent on natural habitats and high nature value farmland. Proc. R. Soc. B. 286, 20191483 (2019).

99. Groen, N. M. et al. A Modern Landscape Ecology of Black-Tailed Godwits: Habitat Selection in Southwest Friesland, The Netherlands. arde 100, 19–28 (2012).

100. Durant, D., Tichit, M., Kernéïs, E. & Fritz, H. Management of agricultural wet grasslands for breeding waders: integrating ecological and livestock system perspectives—a review. Biodivers Conserv 17, 2275–2295 (2008).