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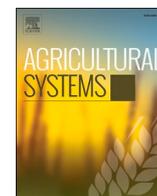
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Review

Beyond agroecology: Agricultural rewilding, a prospect for livestock systems

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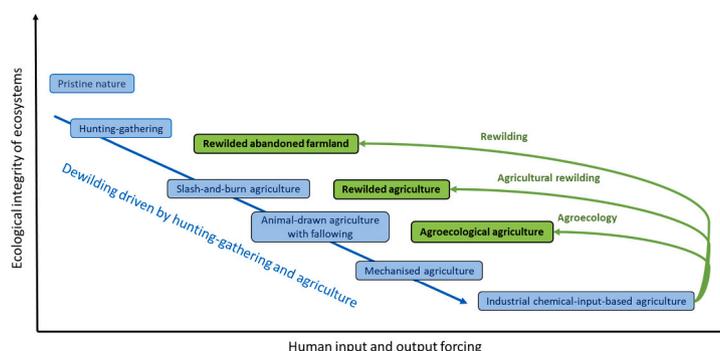
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HIGHLIGHTS

- Rewilding has emerged as a radically different approach to address the erosion of biodiversity
- The potential of rewilding of agricultural systems to conserve and restore biodiversity should be explored
- Agricultural rewilding is an emerging form of land use that we conceptually position between agroecology and rewilding
- Agricultural rewilding may provide a multifunctional model for livestock systems to better respond to societal demands
- Agricultural rewilding's relation to agroecology and rewilding, its forms and its value for farmers remain to be explored

GRAPHICAL ABSTRACT



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ABSTRACT

CONTEXT: Agricultural intensification is a major cause of biodiversity loss. Biodiversity conservation and restoration generally involve human intervention. In comparison, rewilding, a radically different approach to address the erosion of biodiversity, aims to increase the ability of ecological processes to act with little or no human intervention, and thus to enhance biodiversity and the supply of ecosystem services. Rewilding, including that of agricultural systems, has been examined from ecological and social perspectives but rarely from an agricultural perspective.

OBJECTIVE: In this review of the literature and case studies, we (i) analyse whether and how rewilding of agricultural systems, particularly livestock systems, can help conserve and restore biodiversity and offer new prospects, and (ii) identify research questions about rewilding of agricultural systems.

METHODS: We researched literature in the Web of Science Core Collection that focussed on rewilding, agriculture, and interactions between them. We also identified agricultural rewilding projects established for at least five years in the United Kingdom (UK) to analyse their approaches and characteristics.

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RESULTS AND CONCLUSIONS: Agricultural rewilding is an emerging form of land use that we conceptually position on a gradient between agroecology and rewilding. It combines restoration of ecological processes with some degree of agricultural production, most often of herbivores. A selection of 11 agricultural rewilding projects in the UK had areas of 121–4402 ha. The projects targeted 48 key species/breeds, 24 of which were ecosystem engineers: 19 grazers, four pig breeds and Eurasian beavers. The main actions to enhance rewilding were extensive grazing and habitat restoration. The main economic activities were meat or animal sales, tourism and education programmes. Agricultural rewilding may provide a multifunctional model to which livestock systems with herbivores may transition to respond better to environmental concerns. However, because it may lack economic viability and conflict with local culture and traditions, government policies may be needed to encourage more farmers to adopt it.

SIGNIFICANCE: Agricultural rewilding offers new prospects for livestock systems with herbivores. We identified key research questions about its relation to agroecology and rewilding, conditions necessary to implement it, its potential for plant production and its value for farmers. In addition, the forms it can take remain to be explored, and the potential influence of these forms on biodiversity, ecosystem services and environmental impacts needs to be characterised. Exploring the forms that agricultural rewilding may take requires close collaboration among ecologists, animal scientists, agronomists, and social scientists.

1. Introduction

Worldwide, biodiversity (i.e. the diversity within species, between species and of ecosystems) is declining faster than at any time in human history (IPBES, 2019). As agriculture occupies nearly 40% of the world's ice-free land (Foley et al., 2011), the biodiversity status of agricultural landscapes is crucial. Conservation of biodiversity, especially in Europe, depends largely on agroecosystems with a low level of intensity (i.e. agricultural inputs per unit of farmland) (Kleijn et al., 2009). However, farming systems have intensified greatly since the mid-20th century, resulting in homogenisation of agricultural landscapes and increasing use of chemical inputs, which has caused a decrease in farmland biodiversity, especially of plants and arthropods (Tuck et al., 2014).

Livestock production, which drove 65% of global land-use change (e.g. deforestation, a leading cause of biodiversity loss) from 1961 to 2011 (Alexander et al., 2015), now requires 77% of the world's agricultural land to produce its feed (Ritchie and Roser, 2019). Thus, it has strong impacts on biodiversity in agricultural landscapes. Characteristics of livestock systems vary greatly, including which landscape(s) they depend on for their feed. Because landscape complexity favours biodiversity (Birkhofer et al., 2018), heterogeneity of crop mosaics and smaller fields in agricultural landscapes favour biodiversity by offering a variety of habitats, particularly in landscapes with a low proportion of semi-natural area (Sirami et al., 2019). For example, Smith et al. (2019) observed that crop-livestock systems provided greater habitat diversity and native bird density and richness than crop-only systems, due to smaller fields and more woody crops and grasslands. Thus, impacts of livestock systems on biodiversity depend on the landscape(s) from which their feed originates. Furthermore, livestock systems are increasingly criticised for their contribution to other environmental impacts, such as climate change, eutrophication and water use (Poore and Nemecek, 2018), and for their poor record on animal welfare (e.g. von Borell et al. (2009)). Consequently, livestock systems must be redesigned urgently to help solve these problems.

1.1. Agroecology

Agroecology, i.e. “the application of ecological concepts and principles to the design and management of sustainable agroecosystems” (Gliessman, 1998), is increasingly recommended as an approach to improve the sustainability of agricultural systems. As a set of practices, agroecology aims to design complex and resilient agroecosystems that, by “assembling crops, animals, trees, soils and other factors in spatially and temporally diversified schemes, favour natural processes and biological interactions that optimise synergies so that diversified farms are able to sponsor their own soil fertility, crop protection and productivity” (Altieri, 2002). Although studies have recommended a wide variety of practices for agroecological cropping and livestock systems (Dumont

et al., 2013), there is no definitive set of practices that can be labelled as agroecological (Wezel, 2017). HLPE (2019) presents organic agriculture, agroforestry and permaculture as approaches related to agroecology. As organic agriculture requires certification, it is the best-quantified form of agroecology. From 1999 to 2020, organic agricultural land area in the world increased from 11 to 75 million ha (i.e. to 1.6% of agricultural land). In the European Union (EU), 14.9 million ha was organic in 2020, which corresponded to 9.2% of its agricultural land (Willer et al., 2022).

Agroecological livestock systems can be considered biodiversity-based systems, which depend much more on ecosystem services supplied by biological processes than on human inputs (Therond et al., 2017). As these processes depend on the biodiversity in agroecosystems, transitioning to agroecology requires increasing on-farm biodiversity, especially that which supports agricultural production, and managing it with a landscape approach (Duru et al., 2015). Traditional biodiversity conservation and restoration often involve continued human intervention, such as habitat creation or manipulation, culling of invasive species or captive-breeding programs, even in natural areas (Mallon and Price, 2013). In agricultural areas, especially in Europe, agri-environment programmes are based on the observation that certain forms of intervention can yield higher biodiversity and supplies of certain ecosystem services than areas without these interventions (Batáry et al., 2015).

1.2. Rewilding

In contrast to traditional biodiversity conservation based on continued human intervention, rewilding, a much-debated concept in the field of natural-area management, aims to restore the ability of ecological processes to act with little or no human intervention (i.e. “wildness”) to systems at any spatial scale. According to a recent unifying definition, rewilding is “the process of rebuilding, following major human disturbance, a natural ecosystem by restoring natural processes and the complete or near complete food web at all trophic levels as a self-sustaining and resilient ecosystem with biota that would have been present had the disturbance not occurred” (Carver et al., 2021). Rewilding can thus enhance biodiversity and the supply of ecosystem services (i.e. the contributions of ecosystems to human well-being) (Haines-Young and Potschin, 2018). The extent to which rewilding can actually deliver as much biodiversity or other benefits as more targeted approaches remains uncertain, as current projects are still in their infancy (Lorimer et al., 2015). To date, academic debate about rewilding has occurred almost exclusively among ecologists and, to a lesser extent, social scientists (Carver et al., 2021). We believe that rewilding may hold promise for agroecosystems, and we hope that this paper may contribute to broadening the debate by involving agronomists.

During the first 30 years of debate over definitions of “rewilding”

(Jørgensen, 2015), four main forms of rewilding were distinguished (Corlett, 2016): trophic (species introductions to restore top-down trophic interactions), Pleistocene (restoration of a Pleistocene baseline), ecological (allowing ecological processes to regain dominance) and passive (little or no management). These forms of rewilding emphasise little to no human intervention, and consequently rewilding and agriculture are essentially considered to be mutually exclusive (Linnell et al., 2015). Passive rewilding occurs when humans give up control over land (e.g. agriculture, forestry) and leave the land to nature (van der Zanden et al., 2017). Passive rewilding of abandoned farmland is an important process in many regions of the world and one of the main land-use changes in Europe. It occurs primarily in remote, mountainous and less productive areas, which are dominated by extensive pasture-based livestock production. Using a modelling approach, van der Zanden et al. (2017) predicted that 4–11% of the agricultural area in the EU in 2000 may be abandoned by 2040. The effects of land abandonment on biodiversity are strongly debated, especially in Europe, where pasture-dominated habitats inherited from pre-industrial societies are recognised for their high conservation value (Barnaud et al., 2021). Thus, although extensive agricultural systems favour biodiversity (Doxa et al., 2010; Zakkak et al., 2015), sometimes having the highest values for certain measures of biodiversity (especially on High Nature Value (HNV) farmland), other studies have shown significant ecological benefits of passive rewilding (e.g. Navarro and Pereira (2012)). In this conflicting perspective between these two visions of conservation, grazing seems welcome because it can maintain or increase habitat heterogeneity, and thus potentially the species richness, of forest-grassland mosaics (Erdős et al., 2018) and forests themselves (Öllerer et al., 2019).

Forms of rewilding that include more agricultural interventions have been defined: “Rewilding Lite” (delivering wildness while producing some economic benefits, particularly animal products) (Gordon et al., 2021a, 2021b), “agricultural wilding” (encouraging wild-crop production systems in agricultural landscapes) (Vogt, 2021) and “domesticated rewilding” (smaller-scale, with more human intervention and lower ambitions for increasing biodiversity and restoring ecological functions) (Thomas, 2021). As a term, “Rewilding Lite” has the longest history (coined by Carver (2014)), but it is not self-explanatory (describing only what it is not), may be considered pejorative (Fisher, 2021), and has been used relatively little (in ca. 10 publications). In this article, which focusses on rewilding of agricultural systems, we prefer to use the term “agricultural rewilding” in order to recast rewilding of agricultural systems in a more objective and descriptively accurate way, as a step forward, not a step that falls short.

Rethinking agroecosystem management by including rewilding processes may help reverse the current loss of biodiversity, and thus restore the structure, functions and composition of ecosystems that have been disturbed by farming intensification. Ultimately, rewilding highlights the potential of reducing or abstaining from human intervention in certain parts of farms and/or agricultural landscapes, under the hypothesis that differing degrees of land use are complementary and have synergies with respect to biodiversity (Kremen et al., 2021).

In this review of the literature and of case studies of rewilding in agricultural contexts, we explored the potential of rewilding for agriculture, and in particular for livestock systems. As Carver et al. (2021) highlight, rewilding is context-specific; here, we focused on rewilding in an agricultural context and, unlike previous studies of this topic, from an agroecological perspective. We aimed to:

- Bring the rewilding debate into the agricultural science arena, by analysing whether and how rewilding of agricultural systems can help conserve and restore biodiversity and offer new prospects, in particular for livestock systems
- Identify research questions about rewilding of agricultural systems

After describing our methods (2), we examine the concept of rewilding by presenting its forms (3.1), its assessment (3.2), its relation

to food production over time (3.3) and to agricultural systems (3.4), the forms that agricultural rewilding can take (3.5), and a comparison of four animal-based land-use forms that range from industrial agriculture to rewilding (3.6). The research questions identified concern agricultural rewilding’s complementarity with agroecology and rewilding (4.1), the conditions necessary to implement it (4.2), how it should be implemented/optimised (4.3), where it can be adopted (4.4), its potential for plant production (4.5), what it can do for farmers (4.6), and how it should be assessed (4.7).

2. Methods

To address relations between rewilding and agriculture, we performed queries (in April 2021) of the Web of Science Core Collection (SCI-EXPANDED, BKCI-S, ESCI) that focused on rewilding alone (TS = rewild* OR re-wild*), which returned 548 articles, and on rewilding and agriculture (TS = (rewild* OR re-wild*) AND agric*), which returned 81 articles. Of the 10 articles that considered integrating rewilding into agriculture, seven mentioned rewilding of livestock systems. We used the relevant articles to summarise the information that follows about relations between rewilding and agriculture, which contributed to our reflections on rewilding in agricultural systems.

To understand what forms successful agricultural rewilding may take, we searched the literature and Internet for relevant projects with a longer-term history. Given differences in agricultural, environmental, social, and political contexts among regions of the world, the search quickly focused on Europe, specifically the United Kingdom (UK), which appears to be fertile ground for agricultural rewilding. The Rewilding Britain website (<http://rewildingbritain.org.uk>) lists rewilding projects in the UK. Of the 28 projects listed (as of April 2021), we selected those that (i) had some form of agricultural output and (ii) had been engaged in rewilding for at least five years. This process yielded 11 projects, which we analysed to better characterise agricultural wilding in practice.

3. Rewilding: A multifaceted concept

3.1. Forms of rewilding

Pettorelli et al. (2018) compared, among other characteristics, the vision, aim and management interventions of Pleistocene, trophic, ecological and passive rewilding, to which we added agricultural rewilding (Table 1). Agricultural rewilding differs from the others mainly by including more human interventions, specifically harvest of plants and/or animals, along with the restoration of ecological processes. According to our literature review, few articles have discussed agricultural rewilding. This reflects rewilding’s essentially dualistic view of the relationship between human culture and nature, which sees them as separate realms (Linnell et al., 2015). Thus, abandonment of agricultural land is seen as an opportunity for rewilding (Corlett, 2016). In contrast, agricultural rewilding reflects a non-dualistic approach, which is compatible with the traditional practice of biodiversity conservation in Europe (Linnell et al., 2015) and which, to the best of our knowledge, has not been investigated in the agricultural literature.

When animals are included, agricultural rewilding involves grazers, but not necessarily carnivores, since human managers fulfil the role of top predator. Management interventions include fencing in areas (if animals are harvested), potentially introducing species to the ecosystem, particularly in the initial phase, and then harvesting plants and/or animals in order to maintain desired population levels. While the other rewilding forms generally originate in landscapes where agriculture is absent, marginal or has been abandoned (Navarro and Pereira, 2012), agricultural rewilding can be found on land that is either marginal or non-marginal for agriculture on individual farms and/or in agricultural landscapes. Despite continued debate over the utility of distinguishing “rewilding” from “restoration” (Anderson et al., 2019; Hayward et al.,

Table 1
Approaches, associated visions, aims and management interventions of the main forms of rewilding, including agricultural rewilding (adapted from [Pettorelli et al. \(2018\)](#)).

Rewilding approach	Vision	Aim	Management interventions
Pleistocene	Promote large, long-lived species; facilitate the persistence and ecological effectiveness of megafauna	Restore ecological processes lost in the late Pleistocene	Translocation (including ecological replacement)
Trophic	Promote self-regulating biodiverse ecosystems	Restore top-down trophic interactions and associated trophic cascades	Translocation (including ecological replacement)
Ecological	Promote self-regulating biodiverse ecosystems	Restore ecological processes	Translocation (including ecological replacement)
Passive	Reduce human control of landscapes	Restore ecological processes	Little to no management, although intervention may be required early in the process
Agricultural	Promote largely self-regulating biodiverse ecosystems while obtaining economic benefits from agriculture	Combine restoration of ecological processes and biodiversity with plant and/or animal production	Introduction and harvest of plant and/or animal species

2019), all forms of rewilding emphasise minimal human intervention and the influence of fauna (especially large mammals) on ecosystems ([Gordon et al., 2021b](#)).

3.2. Assessing rewilding

[Torres et al. \(2018a\)](#) developed a two-dimensional framework to measure and monitor the progress of rewilding; it characterises an

ecosystem's condition as a function of (i) the intensity of human forcing of natural processes and (ii) the ecosystem's ecological integrity. The former, influenced by current management, is a function of material human inputs to and outputs from the ecosystem. In this respect, it is the inverse of the "human modification" continuum of the wilderness continuum discussed in the rewilding literature (e.g. [Carver et al. \(2021\)](#)). The latter, influenced by human-legacy effects on ecological composition, structure and functions, is a function of three ecological processes: (i) stochastic disturbances, (ii) landscape connectivity and (iii) trophic complexity ([Perino et al., 2019](#)). [Torres et al. \(2018a\)](#) quantified material human inputs and outputs by their human-associated energy, as recommended by [Anderson \(1991\)](#), using a set of indicators that practitioners can easily assess. They likewise developed a set of indicators to assess the three ecological processes that define ecological integrity.

3.3. Evolution of food-production systems

Positioning food-production systems in the framework of [Torres et al. \(2018a\)](#) ([Fig. 1](#)) reveals an evolution from hunting-gathering, to animal-drawn agriculture, to the current industrial chemical-input-based agriculture. Over time, human land-use has aimed to increase plant and animal output, mainly by increasing the use of a wide range of inputs (e.g. fertilisers, pesticides, irrigation, animal feed, machines), which has degraded the ecological integrity of ecosystems ([Fig. 1](#)). This evolution of food-production systems can be considered as a process of "dewilding" that started more than 100,000 years ago with humans driving megafauna extinctions ([Sandom et al., 2014](#)) and accelerated with the advent of agriculture, especially with its industrialisation since the mid-20th century ([IPBES, 2019](#)).

In recent decades, certain agricultural landscapes and farms have evolved in the opposite direction, decreasing material human inputs and improving ecological integrity (i.e. rewilding) ([Fig. 1](#)). This evolution lies along a gradient and takes three forms: agroecology, agricultural rewilding and rewilding (in green). This gradient is similar to that of wildlife-friendly farming (i.e. "reducing the intensity of agricultural management and implementing conservation actions in farmed landscapes"; [Pywell et al., 2012](#)), Rewilding Lite and Rewilding Max ([Gordon et al., 2021b](#)). Transitioning from industrial agriculture to agroecology, the beginning of the gradient, can be considered as the first stage on a trajectory of agricultural rewilding ([Fig. 1](#)).

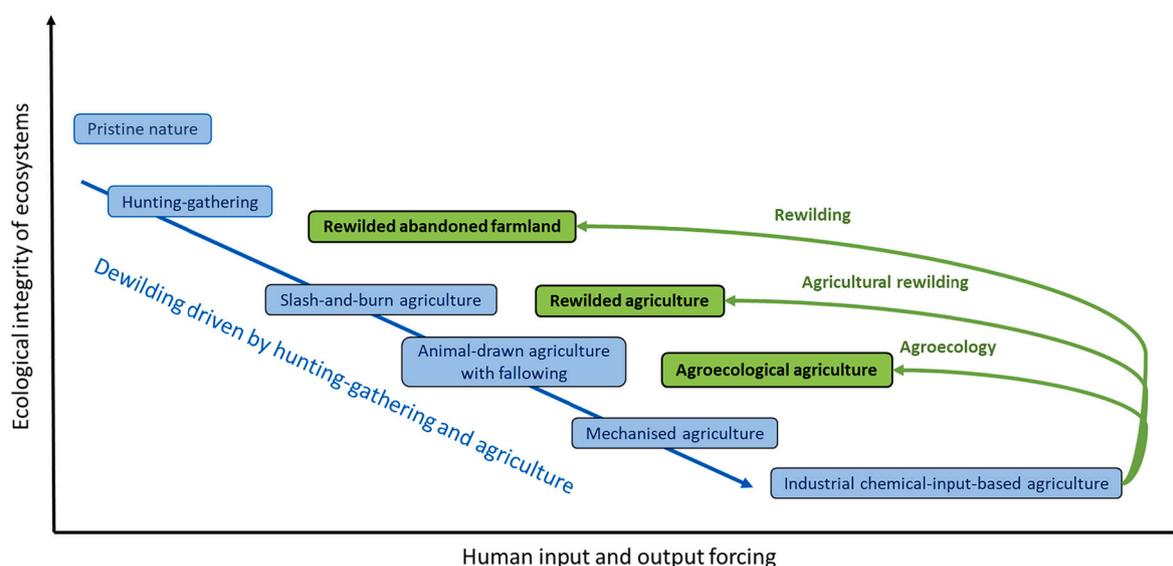


Fig. 1. Over time, human food procurement has involved increased human forcing of natural processes and degraded the ecological integrity of ecosystems. This evolution can be considered as a continuous dewilding process (in blue). Recently, certain agricultural landscapes and farms have decreased human forcing of natural processes and improved the ecological integrity of ecosystems. This evolution takes three forms: agroecology, agricultural rewilding and rewilding (in green). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

3.4. Rewilding of agricultural systems

The bestselling book *Wilding: the Return of Nature to a British Farm* (Tree, 2018) revealed the potential of agricultural rewilding as a prospect for livestock systems to a wide audience. In it, Isabelle Tree related how she and her husband transformed their economically failing dairy farm into the Knepp Wildland project, a haven of rewilded biodiversity. The theoretical foundations of this rewilding were provided by Vera's (2000) influential theory of cyclical vegetation turnover, which posits that the natural vegetation of lowland Europe was not closed forest but a shifting mosaic or park-like landscape in which megaherbivores played an essential ecological role in slowing or preventing tree regeneration in forest clearings. The Knepp Wildland project was not driven by specific goals or target species. Instead, it introduced rustic breeds of domestic herbivores (i.e. longhorn cattle, Exmoor ponies) and pigs (i.e. Tamworth) and wild herbivores (i.e. red, fallow and roe deer) to establish an ecosystem in which nature was given as much freedom as possible. Herbivores and pigs began to be introduced gradually in 2002, and their density by 2010 was such that, due to the absence of large predators and the existence of regulations prohibiting leaving dead animals to decompose, some of them had to be relocated or harvested, which yielded premium organic meat.

In the scientific literature, three recent publications address rewilding in agricultural contexts. Focussing on livestock, Gordon et al. (2021b) distinguished “Rewilding Max [...] with minimal intervention, covering large areas, with largely intact assemblages of species” from “Rewilding Lite [...] in which carefully chosen interventions are employed to achieve as many of the ecological benefits of rewilding, and with some human economic benefits [...] to maximise the area over which ecological benefits [...] are achieved”. They highlight that the two lie on a continuum and can be complementary. As Rewilding Lite “focusses on delivering wildness, with a co-benefit of meat products” (Gordon et al., 2021b), it can provide more income, which makes it more attractive to landowners. Indeed, where natural predators are absent, there will often be no choice but to mimic their predation by harvesting and/or translocating animals. Among the characteristics of Rewilding Lite, Gordon et al. (2021b) emphasised the potential of traditional breeds, especially “eco-shepherding” them in mixed-species herds/flocks (e.g. sheep and goats, with donkeys as draught animals).

Vogt (2021) introduced the term “agricultural wilding” to describe “introducing and conserving wild crops and plants for agricultural purposes, as wild productive systems”. Using the self-developed framework of “Ecological Sensitivity within Human Realities”, she explored its relevance for coffee-farming landscapes, stressing the value of wild

Table 2

Agricultural rewilding projects in the United Kingdom at least five years old (initial source: Rewilding Britain website).

Project, Start year, Area, Management ¹	Description and County	Key species	Actions to enhance rewilding	Engaging people	Economic activities
Ingleborough 1990, 400 ha, G	Rewilding a National Nature Reserve (Yorkshire)	Short-eared owl, Red grouse, Blue grey cattle, Belted Galloway cattle	Habitat restoration, Tree Planting, Grazing control, Natural regeneration	Volunteering, Recreation	Animal production
Purbeck Heaths 1999, 3332 ha, G	Re-establishing natural processes on a National Nature Reserve (Dorset)	Long-horn cattle, North Devon cattle, Horses, Mangalica pigs	Extensive grazing, Habitat restoration, Species reintroduction	Volunteering, Recreation, Local business gains, Stakeholder coordination	High-quality meat production, Camping, Ecotourism, Education programme
Knepp Wildland 2001, 962 ha, P	Failing farm land turned into a site of wildlife abundance (Sussex)	Eurasian beaver, Red deer, Roe deer, Fallow deer, Tamworth pigs, Exmoor ponies, Purple emperor butterfly, White stork, Long-horn cattle	Extensive grazing, Habitat restoration, Species reintroduction	Volunteering	Tourism, Recreation, Business rentals, Education and Wellness programmes, High-quality meat production
RSBP ² Geltsdale 2001, 2157 ha, N	Rewilding a corner of the North Pennines (Cumbria)	Black grouse, Belted Galloway cattle, Exmoor ponies, Curlew, Hen harrier, Short-eared owl	Extensive grazing, Habitat restoration, Tree Planting, Natural regeneration	Volunteering, Recreation, Stakeholder coordination	Animal production
Wild Ennerdale 2003, 4402 ha, G-N-P	Rewilding in the Lake District National Park (Cumbria)	Roe deer, Red deer, Red squirrel, Belted Galloway cattle, Salmon, Marsh fritillary, Arctic char, Freshwater mussels	Extensive grazing, Habitat restoration, Tree Planting, Deer control, Natural regeneration	Volunteering, Stakeholder coordination, Community hub	Animal production
Upcott Grange Farm 2005, 121 ha, P	Changing a highly managed landscape to one of wildlife abundance (Devon)	Eurasian beaver, Exmoor ponies, European mouflon, Water buffalo, White stork, Iron Age pigs, Heck cattle	Extensive grazing, Habitat restoration, Tree Planting, Species reintroduction, Natural regeneration	Volunteering	Tourism, Education programme, Breeding animals for restoration projects
Geltsdale Farm 2009, 2575 ha, P	Rewilding a commercial hill farm (Cumbria)	Ring ouzel, Luing cattle, Curlew, Whinchat, Hen harrier	Extensive grazing, Habitat restoration, Deer control	Volunteering, Recreation	High-quality meat production
RSPB ¹ Haweswater 2012, 2264 ha, N-P	Combining upland wildlife and sustainable farming (Cumbria)	Red squirrel, Belted Galloway cattle, Fell ponies, Salmon, Ring ouzel, Mountain ringlet butterfly, Alpine plants	Extensive grazing, Habitat restoration, Tree Planting	Tourism, Stakeholder coordination, Education programme	Lamb and sheep sales
Stearth Marshes 2014, 468 ha, N	Creating a large-scale working wetland landscape (Somerset)	Otter, Avocet, Marsh harrier, Owls, Egrets, Long-horn cattle, Dexter cattle, Friesian cattle, Rutland sheep	Habitat restoration, Natural regeneration, Grazing reduction	Volunteering, Tourism, Education programme	High-quality meat production, Ecotourism
Wallasea Island 2015, 853 ha, N	Transforming the island back into an intertidal coastal marshland (Essex)	Short-eared owl, Spoonbill, Redshank, Avocet, Black-tailed godwit, Marsh Harrier, Common seal, Mixed cattle	Habitat restoration, Managed coastline realignment ³	Volunteering, Recreation	Animal production, Ecotourism
Wild Somerleyton 2016, 830 ha, P	Rewilding lowland habitats (Norfolk)	Exmoor ponies, Welsh black cattle, Large black pigs, European mouflon, Water buffalo	Extensive grazing, Natural regeneration	Volunteering, Education and Wellness programmes	High-quality meat production, Events and weddings, Ecotourism

¹ G: governmental, P: private, N: non-governmental organisation.

² Royal Society for the Protection of Birds.

³ Controlled inundation of land by moving sea defences inland.

crops and plants in agricultural systems and landscapes as a “significant opportunity for in-situ conservation [...], cultural and nutritional benefit [...], and market value”.

Based on two rewilding sites in England (UK) and expert and stakeholder interviews, Thomas (2021) argued that a unique form of English rewilding is emerging. This “domesticated rewilding” operates at smaller spatial scales with more human intervention and lower ambition to increase biodiversity, restore ecosystem functioning and increase natural autonomy. It may also refer to itself as “wilding”, without the “provocative” prefix “re-” (Thomas, 2021). Martin et al. (2021) similarly observed that in Scotland (UK) a “more pragmatic, tamed, peopled and socially acceptable version” of rewilding has emerged.

3.5. What does agricultural rewilding look like?

The Rewilding Britain website yielded 11 case studies of agricultural rewilding projects at least five years old (Table 2), with areas of 121–4402 ha and start dates of 1990–2016. The management of the projects varied: governmental (two), commercial (four), non-governmental organisation (three) or a combination thereof (two). The projects lay in counties across England, four of them in Cumbria (in the north-west). Their main initial action was to reduce or abandon sheep grazing. The projects targeted 48 key species/breeds, 24 of which were ecosystem engineers (i.e. species that influence the availability of resources to other species (Jones et al., 1994)): 19 grazers, four pig breeds and the Eurasian beaver. The grazers were cattle (10 breeds), deer (three species), horses (three breeds), sheep (two breeds) and water buffalo. Six actions that enhance rewilding were identified: habitat restoration (10 projects), extensive grazing/grazing control or reduction (10), natural regeneration (six), tree planting (five), species reintroduction (three), deer control (two) and managed realignment (i.e. controlled inundation of land by moving sea defences inland) (one). A wide range of ways to engage with people was found: volunteering (10 projects), recreation (five), stakeholder coordination (four), education programmes (three), tourism (two), local business gains (one), and a community hub (one). Economic activities of the projects were (eco)

tourism, recreation or camping (nine); animal production (six); meat production (five); education and wellness programmes (one); and events and weddings (one).

Where large carnivores are present or returning, however, agricultural rewilding projects would differ greatly from those in England. Were carnivores able to return from a surrounding area (e.g. a rewilded zone) and begin preying on grazers, any human intervention would depend upon the desirability of predation for the project, the susceptibility of the grazers to predation, and perhaps the socio-economic context. Predation may be desired, for example to create a “landscape of fear” that influences grazer behaviour and distribution (Gordon et al., 2021b) or to provide carcasses to support populations of scavengers and decomposers (Arrondo et al., 2019). If one objective is to maintain a certain harvest of herbivores, however, one might introduce only herbivores that can better withstand predation by the local carnivores (as Gordon et al. (2021b) propose) or, if the herbivores are susceptible to local predation, perform more intervention (e.g. herders, sheepdogs, control carnivore numbers) or install stronger fences to further dissuade predators.

3.6. Comparison of land-use forms

Considering the entire range of animal-based forms of land use, we compare industrial agriculture to the forms that lie along the gradient of agroecology, agricultural rewilding and rewilding (Table 3). We consider industrial agriculture and agroecology as broad archetypes that correspond to the strategies of “land sparing” and “land sharing”, respectively (Kremen, 2015). Industrial agriculture is based on chemical inputs, whereas agroecology has a solid theoretical underpinning and international acceptance “as a science, a set of practices and a social movement” (Wezel et al., 2020). Agroecological practices are applied in a variety of types of agriculture (e.g. wildlife-friendly, HNV, biodiversity-based, regenerative, ecological, low-input, extensive) (Therond et al., 2017).

Industrial livestock production aims to meet growing demand for animal products while reducing impacts per unit of product by increasing input-use efficiency (Röös et al., 2017). Based on large, highly

Table 3
Characteristics of four animal-based forms of land use, in order of increasing ecological integrity of ecosystems (inspired by Clay et al., 2020).

Characteristic	Industrial livestock production	Agroecological livestock system	Agricultural rewilding	Rewilding
Premise	Demand for animal food is large and increasing; increasing input-use efficiency decreases environmental impacts per unit of product	Replacing human inputs with natural processes creates self-sufficient production-consumption systems that optimise local knowledge, reduce environmental impacts and enhance food sovereignty and justice	Grazers and other animal ecosystem engineers can transform farmland into a biodiverse ecosystem, which allows for some harvest	Rewilding can promote self-sustaining ecosystems and enhance the conservation status of biodiversity
System characteristics	Large farms, often in regions of high animal density, using commercial breeds and globally sourced feeds to produce a single livestock species, raised indoors, for national and global markets	Diversified crop-livestock farms, using local breeds, raising several livestock species fully or largely outdoors, for local markets	Large areas where a diverse mixture of herbivores and sometimes pigs are managed to develop self-sustaining ecosystems, which restores native biodiversity and ecological processes	Large areas where a diverse mixture of herbivores and sometimes carnivores develop self-sustaining ecosystems, which protects native biodiversity and ecological processes
Management practices	Intensive use of human inputs such as feed, antibiotics and buildings; frequent need to manage excess animal manure	Use of natural processes and locally produced feed, fertilised with farm manure; preservation of on-farm biodiversity	Introduction and regular harvest of traditional livestock and wild herbivores	Introduction of functionally important communities of species, in particular large herbivores and carnivores
Strengths	Higher productivity per unit of land	Lower environmental impacts, favourable for biodiversity, higher animal welfare, resilient to changes	Excellent for biodiversity and provision of ecosystem services, resilient to changes	Best for biodiversity, ecological integrity and ecosystem services
Weaknesses	Lower animal welfare, higher environmental impact at the landscape level	Lower productivity per unit of land	May lack consideration of local culture and traditions, lower productivity	May lack consideration of local culture and traditions, conflict with agriculture
Transformation from industrial agriculture suggested or required	–	High degree of transformation, relevant mainly for small, mixed crop-livestock systems	High degree of transformation, relevant mainly for large extensive livestock systems and/or marginal farmland	Very high degree of transformation, relevant mainly for degraded or marginal farmland

productive specialised farms, it has higher input use and lower animal welfare, and produces for national and global markets (IPES-Food, 2016; Clay et al., 2020). In regions of high animal density, environmental impacts at the landscape level are higher (IPES-Food, 2016).

In comparison, agroecological livestock systems are diversified crop-livestock farms that raise livestock species for local markets (IPES-Food, 2016). They rely on on-farm biodiversity because it replaces human inputs with natural processes (Kremen et al., 2012). They aim to enhance food sovereignty (IPES-Food, 2016). Compared to industrial systems, they have lower environmental impacts and productivity per unit of land, but higher animal welfare (Poux and Aubert, 2018).

Agricultural rewilding's chief aim is to restore native biodiversity and ecological processes, with plant and/or animal production as a co-benefit. A mix of hardy domesticated and wild herbivores and sometimes pigs is introduced and regularly harvested on areas generally larger than those of livestock farms. It differs from agroecological systems (e.g. wildlife-friendly, HNV) by adhering more closely to Carver et al.'s (2021) 10 principles of rewilding, particularly the restoration of trophic interactions via large herbivores, with an aim of ultimately supporting self-sustaining ecosystems. Compared to agroecological systems, agricultural rewilding likely has lower environmental impacts and certainly lower productivity (Balfour et al., 2021) per unit of land. However, it may conflict with local culture and traditions (Tree, 2018).

Rewilding's focus is to restore natural processes and (near-)complete food webs. Populations of wild plants, herbivores and sometimes carnivores develop on areas generally much larger than those of livestock farms. Rewilding favours biodiversity and ecological integrity but may conflict with agriculture and local culture and traditions (Lorimer et al., 2015; Wynne-Jones et al., 2018).

We have defined agricultural rewilding as distinct from agroecology and rewilding, but both agroecology and rewilding have multiple definitions, and agroecology in particular is a fuzzy concept without clearly defined boundaries (Wezel, 2017). Nevertheless, we propose agricultural rewilding as a conceptual perspective that is positioned between agroecology and rewilding. Biodiversity is central to both agroecology and agricultural rewilding; the main difference between them is the degree of human intervention, and thus agricultural productivity. Agroecology and agricultural rewilding can be considered as two ends of a gradient, with intermediate situations. Similarly, self-sustaining ecosystems are central to both agricultural rewilding and rewilding, which can be considered as two ends of another gradient, with intermediate degrees of human intervention between them. Systems may move along this gradient over time depending on objectives for agricultural productivity and ecological integrity, which will determine the degree of human intervention.

4. Questions for agricultural rewilding research

Supporting the insertion of agricultural rewilding into this conceptual niche, clarifying its definition and implementing it effectively will require additional research through close collaboration among ecologists, animal scientists, agronomists, and social scientists. Thus, here we formulate research questions about agricultural rewilding and provide initial responses.

4.1. Can agricultural rewilding complement agroecology and rewilding?

Gordon et al. (2021b) suggest that, although advocates of each form of rewilding often criticise each other, Rewilding Lite can complement Rewilding Max because each can be applied to different parts of the landscape. According to Carver et al. (2021), rewilding uses landscape-scale planning to consider core areas (for self-sustaining ecosystems), connectivity (to promote movement and increase resilience) and co-existence (between wild species and humans). Embedding wild ecosystems (i.e. rewilding) in an agriculturally rewilded matrix, especially if ecological corridors are present (Torres et al., 2018a), could increase the

amount of effective habitat for many species that otherwise might not be able to maintain viable populations in the landscape. Similarly, for forestry, Morizot (2020) cites the Network for Forestry Alternatives, which recommends allowing "free evolution" on 10% of all forest area in France, while implementing "non-violent" forestry (i.e. continuing timber extraction while considering the regeneration and resilience of the forest ecosystem) on the remaining 90%.

As mentioned, the extent to which agricultural rewilding and agroecology display synergies or antagonisms also merits further investigation. Rather than relying on human inputs, agroecology relies on biodiversity, which agriculturally rewilded areas may supply. However, agricultural rewilding may also conflict with agroecology; for example, wild herbivores and cropped fields do not necessarily mix well (Torres et al., 2018b).

4.2. What conditions (e.g. ecological, socioeconomic) are necessary to implement agricultural rewilding?

Agricultural rewilding is of interest for commercial farmers and other stakeholders, such as governmental agencies and non-governmental organisations (Table 2), and involving local stakeholders could ease implementation of agricultural rewilding projects by considering and understanding societal and historical issues of the agroecosystems in which the projects are based (Thomas, 2021). Attention should be paid to potential obstacles to agricultural rewilding and how to address them. For example, regulations for animal welfare, biosecurity and age at slaughter may render agricultural rewilding difficult to implement. Because agricultural rewilding may not align with the values of many farmers, government policies may be needed to encourage more farmers to adopt it. Currently, subsidies from the EU's Common Agricultural Policy (CAP) that provide incentives for farmers to maintain or expand farmland have halted or reversed rewilding progress in certain areas of Europe (Segar et al., 2021).

In the context of the EU Green Deal and its "Farm to Fork" strategy, rewilding, in particular via extensive grazing, may contribute to EU targets for biodiversity, ecosystem services, climate adaptation, wildfire prevention and landscape management (Bezdicikova and Helmer, 2021). Favouring extensive grazing would require, among other actions, amending CAP definitions of "grasslands" to include scrublands, wetlands, woodlands and wood pastures; increasing the flexibility of Agri-Environment-Climate Measures to adapt to local conditions and habitat requirements; and increasing payment levels for extensive grazing relative to intensive land uses (Pe'er et al., 2021). In the post-Brexit UK, the 2020 Agriculture Act (UK Parliament, 2020) has replaced the CAP. It will pay farmers to produce "public goods", such as environmental or animal welfare improvements, thus providing opportunities for rewilding agricultural land (Rewilding Britain, 2021). Post-Brexit environmental and agriculture legislation could benefit rewilding if it is implemented effectively (Klaar et al., 2020).

4.3. How should agricultural rewilding be implemented/optimised?

Few documented examples of agricultural rewilding exist, and it is unknown which forms are most promising. For agricultural rewilding that yields animals, several research avenues can be identified. Clearly, agricultural rewilding requires animals that can thrive "in the wild". Real-life examples of agricultural rewilding suggest that traditional grazers and pigs fare best, but it is largely unknown which species combinations best meet the multiple objectives that agricultural rewilding may have. As Gordon et al. (2021a, 2021b) emphasise, intended ecological outcomes of rewilding projects must be clearly stated from the outset and then managed adaptively.

Interestingly, animal science has only recently started to explore the strengths and weaknesses of multi-species livestock farming for farm sustainability, as reported by Martin et al. (2020). Some of their findings may be of interest for agricultural rewilding, such as the potential to

combine ruminants and monogastric animals (e.g. cattle and poultry) due to their complementary resource-acquisition strategies and ability to reduce parasite pressure (see also [Gordon et al. \(2021b\)](#)). This issue, as well as the combined use of traditional domestic animals and wild animals, merits further investigation in the context of agricultural rewilding.

The timing of actions when initiating agricultural rewilding may be another subject worth investigating. [Tree \(2018\)](#) reports some experiences of the Knepp Wildland project in this respect, such as the need to (i) deplete soil mineral nitrogen before establishing wildflower meadows on intensively farmed land and (ii) give vegetation a head start by rewilding it first, before gradually increasing grazer densities.

4.4. Where can agricultural rewilding be adopted?

The spatial scale(s) for agricultural rewilding warrants investigation. Obviously, rewilding large areas is attractive, as they can support more viable populations of larger species ([Root-Bernstein et al., 2017](#)). The longer-term agricultural rewilding projects listed by Rewilding Britain had a mean area (1669 ha) much larger than that of the average farm in the UK (86 ha). To what extent and under what circumstances rewilding at smaller scales (e.g. less productive parts of farms) may be of interest remains to be investigated.

Like rewilding, agricultural rewilding is likely to be easiest to adopt in areas that are already managed less intensively, such as land that is marginal for agriculture. Rather than abandoning agricultural land in such agroecosystems for subsequent rewilding, it can be agriculturally rewilded. Again like rewilding, however, agricultural rewilding may have the strongest influence on enhancing biodiversity in areas that are managed intensively, but this remains to be investigated.

The agricultural rewilding projects identified in the UK began in diversified agroecosystems that contained specific higher-diversity habitats (e.g. watercourses, marshes). It would be interesting to investigate to what extent the initial diversity of the agricultural landscape and/or the presence of specific habitats (especially sources of fresh water) influence the ability of an agricultural rewilding project to enhance biodiversity and remain financially viable. For the latter, ecotourism is a common source of revenue in the UK projects, but it depends greatly on a project's proximity to population centres, and it can have undesired effects (e.g. habitat degradation).

4.5. What potential does agricultural rewilding have for plant production?

Large herbivores are central to rewilding, and all 11 longer-term agricultural rewilding projects described by Rewilding Britain that we selected involve extensive grazing by domestic and/or wild grazers. Pigs can contribute to agricultural rewilding given their potential as ecosystem engineers and as a source of meat. Plants are essential to these rewilding projects, but not as outputs. The potential of agricultural rewilding to yield plant products (alone or along with animal products) remains to be explored. [Vogt \(2021\)](#) recommends introducing wild crops and plants in agricultural landscapes as a means of in-situ conservation and production, as exemplified by wild coffee systems. [Fukuoka \(1978\)](#) encourages a "natural farming" approach, called "do-nothing farming", whose four principles are (i) no cultivation, (ii) no chemical fertilisers or prepared composts, (iii) no weeding by tillage or herbicides and (iv) no dependence on chemicals. In a somewhat similar vein, [Mollison \(1988\)](#) defines permaculture as "the conscious design and maintenance of agriculturally productive ecosystems which have the diversity, stability, and resilience of natural ecosystems.". Both natural farming and permaculture may inspire forms of agricultural rewilding that yield plants.

4.6. What can agricultural rewilding do for livestock farmers?

Although the value and attractiveness of agricultural rewilding to society in general are obvious, one key question is: what can it do for

livestock farmers? Per unit of land, animal production of agricultural rewilding is low, so the potential of other sources of commercial income (e.g. tourism, recreation, education) and/or public subsidies (e.g. payment for ecosystem services) will be crucial in determining whether farmers decide to transition to agricultural rewilding. As rewilding favours carbon sequestration in soil and woody biomass ([van der Zanden et al., 2017](#)), rewilding part of a farm's land may allow carbon-neutral animal products to be produced (e.g. [Mayberry et al. \(2019\)](#)). Depending on local soil and climate conditions, opportunities for producing products or services, and the availability of subsidy schemes, farmers may position their farms somewhere between agroecology and rewilding to deliver the combination of products and services that suits them best.

4.7. How should agricultural rewilding be assessed?

The potential of industrial agriculture and agroecology to satisfy a range of societal demands is well documented, but this is less true for rewilding, and the potential of agricultural rewilding to do so is largely unknown. Consequently, reflecting on how to assess agricultural rewilding as a form of land use, in particular compared to agroecology and rewilding, is essential. In our opinion, this assessment should be results-based ([Herzon et al., 2018](#)) and include a wide range of criteria, such as biodiversity; provisioning, regulating and maintenance, and cultural ecosystem services; and several environmental impacts. This kind of multi-criteria assessment may identify synergies and trade-offs among the criteria, as illustrated in [Fig. 2](#), which shows examples of potential values of some indicators. It should also quantify strengths and weaknesses of agricultural rewilding relative to those of other land-use forms and explore the potential of different forms of agricultural rewilding. To our knowledge, only one study of this type has been published: [Balfour et al. \(2021\)](#) assessed biodiversity and ecosystem services of six sites in England, including an agricultural rewilding project (i.e. Knepp Wildland). Studies that examine additional agricultural rewilding projects (e.g. [Gordon et al. \(2021a\)](#)) may help assess the potential of agricultural rewilding further. Social and economic performances of agricultural rewilding should also be assessed, particularly social acceptability and commercial income.

5. Conclusions

Agriculture, in particular livestock production, has contributed greatly to biodiversity loss and other environmental impacts (e.g. climate change, water pollution) through its land use. Due to these and other problems (e.g. low animal welfare), livestock systems are challenged to find new ways forward. We recommend agricultural rewilding – the promotion of largely self-regulating biodiverse ecosystems compatible with harvesting, conceptually positioned between agroecology and rewilding – which can take a wide range of forms. It may provide a multifunctional model to which livestock farms, especially those with herbivores, may transition to respond better to environmental concerns. Transitioning from industrial to agroecological livestock systems reduces environmental impacts; favours biodiversity; and enhances regulating and maintenance ecosystem services, as well as cultural ecosystem services. Agricultural rewilding may allow livestock systems with herbivores to further reduce their impacts, restore biodiversity and deliver more ecosystem services, but the degree to which it can do so remains to be quantified. Its complementarity with agroecology and rewilding; the conditions, forms and spatial contexts for its implementation; its potential for plant production and livestock farmers; and how it should be assessed are key questions for agricultural system, ecological, and social-science research.

Author contributions

Literature review: AM, MSC, HvdW, LM.

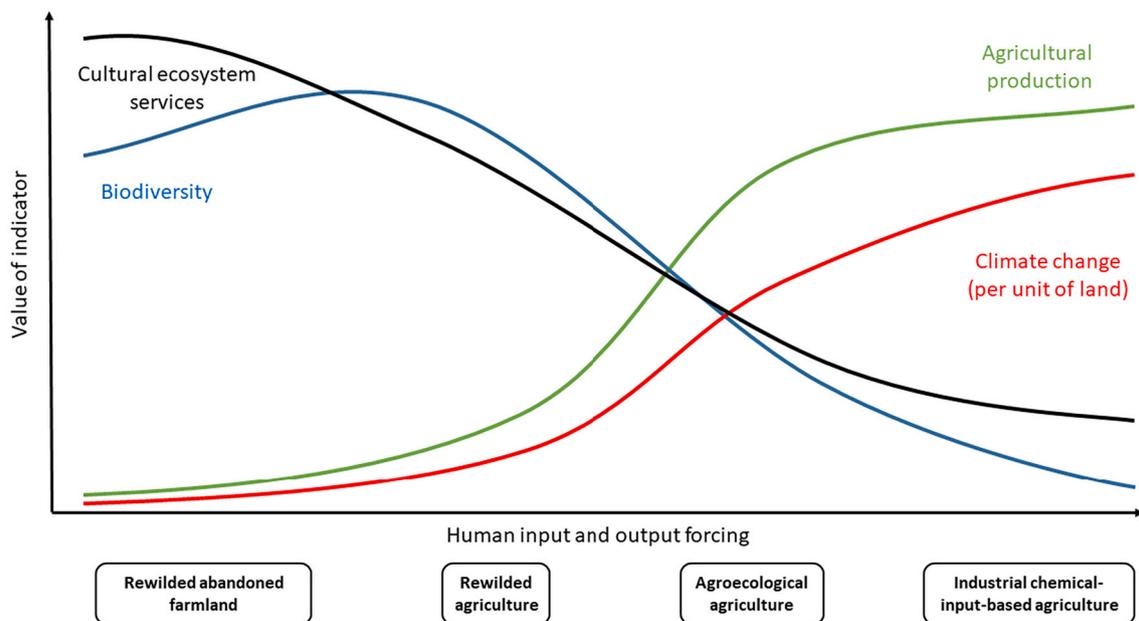


Fig. 2. Conceptual representation of examples of potential values of selected performance indicators to assess four land-use forms.

Case study analysis: HdvW, MSC, AM, LM.
 Writing, original draft: AM, HvdW, MSC, LM.
 Writing, review & editing: MSC, HvdW, AM, LM.

Declaration of Competing Interest

The authors declare no competing interests.

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