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PERSPECTIVE

Interdisciplinary insights on climate-smart rewilding: Lessons from pioneering Dutch river transformations

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Abstract With climate and biodiversity crises intensifying, integrated solutions are urgently needed. Rewilding offers a promising approach to ecosystem restoration and climate adaptation. However, challenges regarding land-use, societal conflicts and governance can hinder its implementation. This paper discusses the elements of transformative thinking that can support rewilding implementation and establishment as an innovative approach to ecological recovery. We draw on the lessons learned from over 30 years of rewilding in the Gelderse Poort, the Netherlands. The floodplains in this area have been transformed from a predominantly dry, agricultural landscape into a dynamic riverine nature landscape with a broader range of socio-economic services in a peri-urban area and densely populated region. We describe how a readiness to embrace uncertainty, supportive policies, dedicated champions and innovative funding partnerships were crucial for this rewilding project. We explore how these lessons can inform rewilding efforts in Europe to deliver both climate resilience and biodiversity benefits.

Keywords Adaptive management · Environmental policy instruments · Flood risk management · Nature-based solutions · Riverine forest · Transformative change

Tim de Kruiff and Cecilia Fraccaroli have contributed equally to this work.

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INTRODUCTION

To bend the curve of biodiversity decline, effective conservation and large-scale restoration efforts are urgently needed (CBD 2022). At the same time, measures to adapt to and mitigate climate change are crucially needed as well. Rewilding, by giving more room to natural processes, has the potential to contribute to both biodiversity recovery and to offer nature-based solutions for climate change adaptation and mitigation (Bakker and Svenning 2018). Rewilding is generally framed as a process-oriented approach that aims to restore the autonomy of ecological dynamics and increase "wildness" by reducing human control (Perino et al. 2019; Carver et al. 2021; Massenberg et al. 2023). Following a framework by Perino et al. (2019), rewilding specifically targets three interacting ecological processes: trophic complexity (e.g., through the reintroduction of large mammals), stochastic disturbances (e.g., allowing natural flooding), and dispersal (e.g., by restoring habitat connectivity). Rewilding is often implemented with a social component, promoting local economic development and reconnection of people with nature (Jepson et al. 2018, 2019; Faure et al. 2024).

However, evidence of rewilding's combined benefits for biodiversity, climate change adaptation and mitigation remains limited, as most rewilding initiatives have been evaluated primarily for their biodiversity outcomes (Griscom et al. 2017; Kloibhofer et al. 2025; Stark et al. 2025). Nonetheless, the literature shows that rewilding can contribute directly to climate-related goals. Trophic rewilding has potential for carbon sequestration and climate mitigation (Cromsigt et al. 2018; Schmitz et al. 2023) or may reduce wildfire risk by managing fuel loads (Rouet-Leduc et al. 2021). Improving connectivity and dispersal may also facilitate functional adaptation to shifting climates (Kremer et al. 2012; Selwyn et al. 2024). Building on this emerging evidence, the term "climate-smart rewilding" has been recently coined by Stark et al. (2025) to denote a specific subset of rewilding strategies that are explicitly designed and managed to jointly enhance biodiversity, support climate change mitigation and adaptation and generate socio-economic benefits (Stark et al. 2025; Kloibhofer et al. 2025).

While climate-smart rewilding might hold potential, its successful implementation navigates complex challenges. In Europe, rewilding efforts are often shaped not only by ecological opportunities but also by social objectives linked to land-use legacies, and conflicting societal values, as well as attachment to cultural landscapes (Vera 2010; Ceauşu et al. 2015; Jepson 2019; Van Meerbeek et al. 2019; de Kruiff, 2025a). Spatial, political and social constraints can limit the desirability and feasibility of large-scale rewilding initiatives (Faure et al. 2024). This raises practical questions: how to create legitimate space for climate-smart rewilding, how to leverage local interests and how to meet policy requirements and secure funding? In short, how can climate-smart rewilding be implemented successfully?

Rewilding has been argued to not only represent a marginal change, but to have transformative potential (Jepson and Blythe 2020), offering a different model to current land-use, ecology, economy and views alike. Transformative change is seen as "a *fundamental, system-wide reorganisation across technological, economic and social factors, including paradigms, goals and values*" (IPBES et al. 2019, p. 14). Although it is a diffuse concept with differing conceptual interpretations in literature (Feola 2015; Biesbroek et al. 2026), transformative change particularly in the context of climate change adaptation is seen as sharing some similarities (Biesbroek et al. 2026). Transformative adaptation to climate change pertains to systemic change addressing root causes, not piecemeal solutions treating symptoms (Pal et al. 2019; Biesbroek et al. 2026). They are sustainable and long-term changes, with cascading effects and with impact at scale, that engage with distributive justice and impact power dynamics and governance structures (Lonsdale et al. 2015; Pal et al. 2019; Biesbroek et al. 2026). Often it is a complex process, occurring over long timeframes, resulting from the interaction between multiple policy processes, interventions and stakeholders (Scolobig et al. 2023), that is context specific (Biesbroek et al. 2026). In this paper, we argue that climate-smart rewilding can indeed be transformative in practice. We draw on the Dutch Gelderse Poort area, which is part of the larger "*Room for the River*" programme (ARK, 2025; Rijkswaterstaat 2026) in the Netherlands, as an early and evolving example of rewilding in action. While climate-smart rewilding is still an emerging concept, the Gelderse Poort area can be considered a practical pioneering example, having developed over the last 35 years to reduce flood risk and improve conditions for nature simultaneously. The project continues to expand beyond its primary goals of ecosystem restoration and flood risk reduction, impacting both local communities and the wider European rewilding movement (Jepson et al. 2018; Jepson and Blythe 2020).

In this paper, we analyse the implementation of this pioneering rewilding initiative—an early example illustrating key principles of climate-smart rewilding—and identify the main factors that enabled its development. We highlight how climate-smart rewilding in the Gelderse Poort constitutes (elements of) transformative change, providing empirical support for the claims in Jepson and Blythe (2020). To answer these questions, we draw on literature and an expert workshop discussion with key people behind the vision of Gelderse Poort to document the rewilding implementation from an ecological and socio-economic perspective. With this approach, we subsequently look beyond this pioneering rewilding area and derive lessons learned that can inspire climate-smart rewilding initiatives at other sites in Europe or worldwide. The expert workshop was composed of a field visit to several areas in Gelderse Poort and a structured discussion to elicit expert opinions. The discussion involved key stakeholders who have been or are involved in the vision, design, management and monitoring of rewilding in the Gelderse Poort ($n=12$, see Table S1) to identify narratives by local actor groups, which we then categorised into crucial factors across ecological, societal and socio-economic contexts (see questions in S2).

We drew from a wide range of sources partly mapped during the workshop, including peer-reviewed and grey literature, policy reports, media articles, cost–benefit analyses and management plans. To offer a comprehensive view of the enablers and constraints of rewilding in the Gelderse Poort, we gathered information from disciplines of (i) ecology, (ii) social science and (iii) economics. In this way, we provide interdisciplinary insights into the possible drivers that shaped land-use decisions and rewilding.

REWILDING IN THE GELDERSE POORT

The Gelderse Poort is a riverine landscape, generally defined as the upstream riverine area from the cities of Arnhem and Nijmegen, and bounded by the border with Germany. Nature development in the Gelderse Poort started in the late 1980s, when this was sometimes also called "new nature". This development referred to land-use change mainly from agriculture in favour of nature. As such, this nature was referred to as "new" in contrast to already existing nature reserves. This approach can be considered a form of active rewilding, where multiple measures are taken before nature is left to develop itself (Jepson et al. 2018). The general ideas behind this type of nature development have formed the basis for the wider approach to rewilding in Europe, inspiring, for example, the vision of Rewilding Europe (Jepson et al. 2018), with the Gelderse Poort being seen retroactively as a key rewilding site before the term became commonplace in Europe (Drenthen 2018) (Fig. 1).

The Sandoz chemical spill in 1986 brought the poor ecological state of the Rhine River into focus (Boos-Hersberger 1997). To address the poor state of nature in the river landscape, the document "Plan Stork" ("Plan Ooievaar" in Dutch) reimagined how the ecological state could be improved, while also addressing flood risk. In this original plan, the functions of nature and agriculture would be spatially separated near the Rhine River in the Netherlands, where agriculture would move out of the floodplains. This would allow for the reintroduction of flooding dynamics and storage of water in the outer dike river floodplains. This visionary plan served as the basis for nature development in the Gelderse Poort, which started in a 3-ha plot in Millingerwaard. This small-scale start received support from the major NGO WWF NL in the early 1990s. This was followed by two large river floods in the Netherlands that resulted in the evacuation of hundreds of thousands of people in the mid-1990s. This led to a wider recognition in the Netherlands that a change in the water management approach was necessary (Wolsink 2006). As a result, the Room for the River national programme institutionalised a rewilding approach to river management in most of the landscape. Since the 1990s, the rewilding approach has expanded in the Gelderse Poort, with now over 5.500 ha of new nature realised (ARK 2025), as highlighted in Fig. 2. This is now generally seen as a successful example of nature development for the rest of the Netherlands, with iconic species such as the white-tailed eagle currently breeding in the area.

Key rewilding actions in the Gelderse Poort include a reallocation of farming activities out of the floodplains, as well as opening side channels and water bodies connected to the river. Floodplains have also been lowered, restoring seasonal flooding regimes with dynamic water levels and inundation of parts of the floodplain over the year. This provides gradients of shelter and improved water quality, contributing to the development of aquatic and wetland biodiversity. The landscape is made of natural grassland, riverine forests, marshes, lakes and river dunes with minimal maintenance, each with its own diverse ecosystem of animals and plants. To maintain the wetland and floodplain vegetation, trophic rewilding in the form of the reintroduction of large herbivores took place. Free-ranging Galloway cattle and Konik horses were reintroduced, as well as beavers as ecosystem engineers.

Gelderse Poort addresses all three "dimensions of rewilding"; stochastic disturbances, trophic complexity and dispersal (Perino et al. 2019). Stochastic disturbances occur in the form of flooding events and seasonal water level fluctuations. Trophic complexity is increased through the reintroduction of large herbivores and their cascading

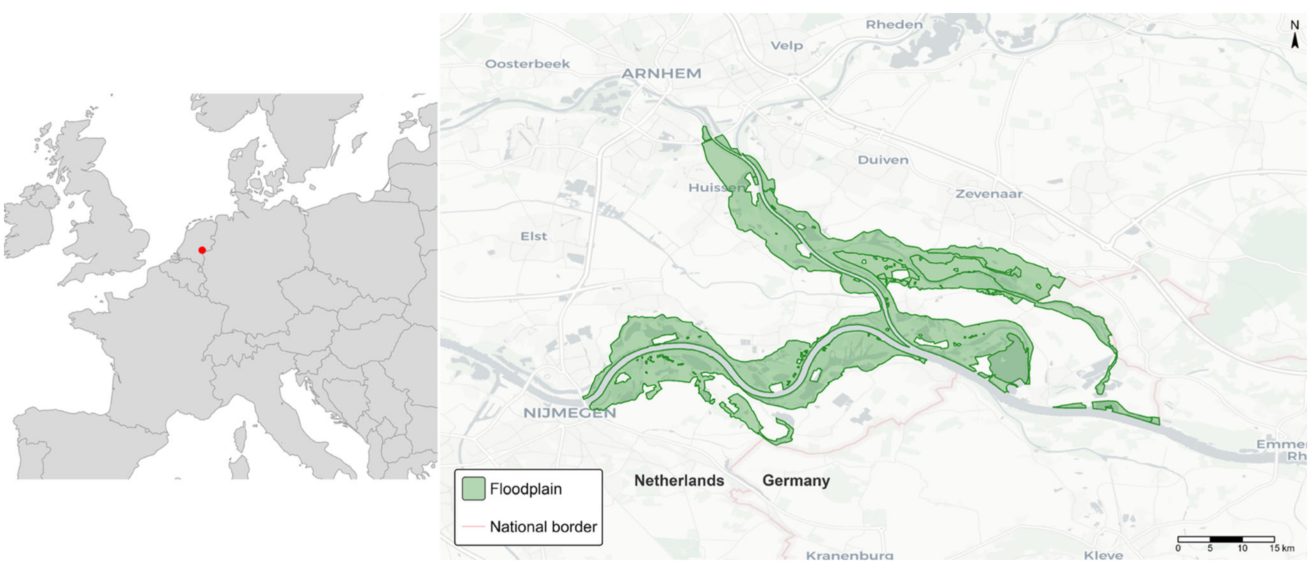

Fig. 1 Location of Gelderse Poort in the Netherlands, showing the rewilding area along the river Waal and nearby cities Nijmegen and Arnhem and the border between the Netherlands and Germany.
Source: OSM maps

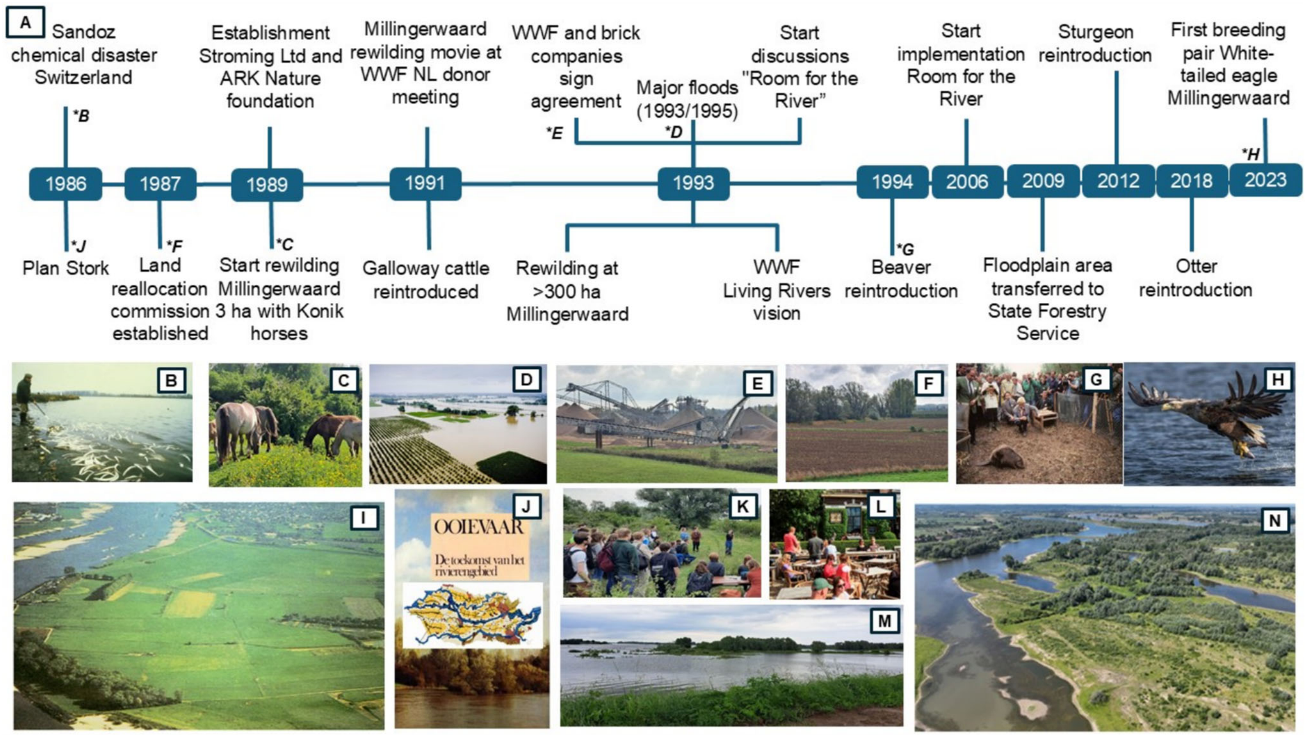

Fig. 2 Timeline of key events in the Gelderse Poort development from 1986 to 2023 (**A**) and illustrative images of some of these events (**B–N**). Images: Millingerwaard before (**I**) and after (**N**) rewilding; outreach events (**K**); local hospitality business (**L**) and a lagoon storing water in Gelderse Poort (**M**). Photo credits: Badische Zeitung/dapd (**B**); Nacho Villar (**C**, **E**, **F**, **L**, **M**); Bert Ooms (**H**); Wouter Helmer (**I**); Clementien & Plan Ooievaar (**J**); Ineke Radstaat (**K**)

effects on biodiversity. Dispersal is addressed both through the flooding events, bringing seeds and organisms from upstream of the river, as well as through connected terrestrial habitats and propagule dispersal by herbivores (including birds and mammals) or wind and water. Rewilding has developed over time in the Gelderse Poort, as illustrated in Fig. 3A–C, transitioning from agriculture to more space for the water, and developing a diversity of landscapes including natural grasslands, shrubs, reeds, dunes and wet and dry forests.

To measure the development of rewilding sites along the dimensions of rewilding, Torres et al. (2018) developed a rewilding score metric on a 0–1 scale, where 1 is the highest level of rewilding. This score measures rewilding-based changes in human input and output (y axis) and ecological integrity (x axis) over time (Fig. 3D), and is based upon responses to a list of indicators. The Millingerwaard, the oldest part of the wider Gelderse Poort area, scored 0.10 on this scale in 1990 and increased to 0.29 in 2017 (Torres et al. 2018). Based on the same evaluation methodology, responses were gathered from the current site manager to update the score (Supplementary Materials). This score reached 0.52 in 2023, mostly due to increases in successional development of vegetation, aquatic connectivity and management of invasive species (Roos 2023; Personal communication, 2025). The underlying calculation data and description of changes over time can be found as part of the Supplementary Materials (S3). This development, as visualised in Fig. 3D, highlights the development of the Gelderse Poort as a rewilding site over time.

CRUCIAL FACTORS FOR REWILDING IN THE GELDERSE POORT

In this section, we present crucial factors for rewilding in the Gelderse Poort according to our stakeholder interactions, clustered by socio-political, ecological, economic and cross-cutting disciplines in Fig. 4. The separation between these categories is not always strict, as many factors intersect multiple domains. However, this structure reflects both the logic of the analysis and an overview of the main factors for the included disciplines.

Window of opportunity for transformative change

In the 1990s, major floods of the rivers in the Netherlands led to the evacuation of hundreds of thousands of citizens from their homes. In 1993, this led to the evacuation of

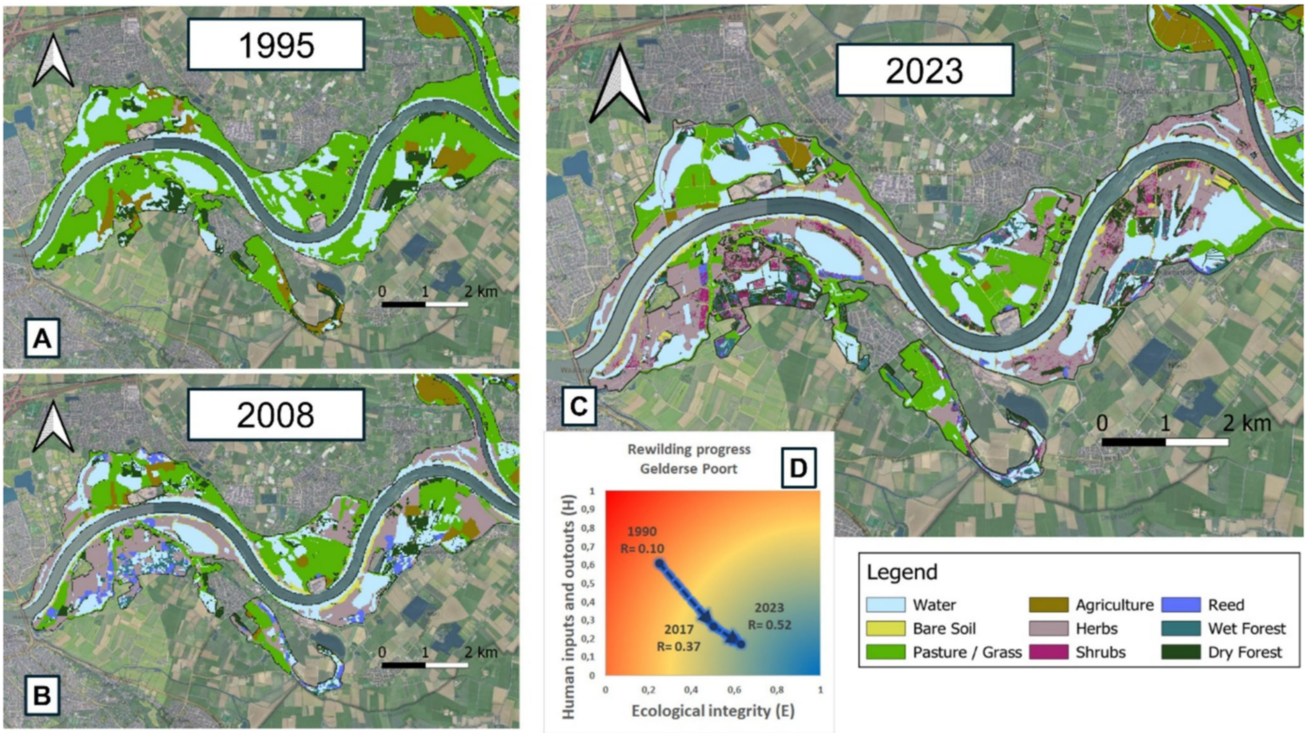

Fig. 3 Rewilding progress in the Gelderse Poort. Starting from an agricultural grassland-dominated riverine landscape in the 1990s (panel A), Gelderse Poort developed into a landscape dominated by early-stage ecological successional stages in the early 2000s (panel B), to the highly ecologically heterogeneous landscape found today (panel C). Panel D shows how this progress translates to the rewilding score by Torres et al. (2018) after more than three decades of decreasing *human inputs and outputs* in the ecosystem (y axis) and an increase in *ecological integrity* (x axis) for the Millingerwaard, the oldest part of the wider Gelderse Poort area. Map developed by Guus Maessen. Updated rewilding score based on responses gathered in Roos (2023)

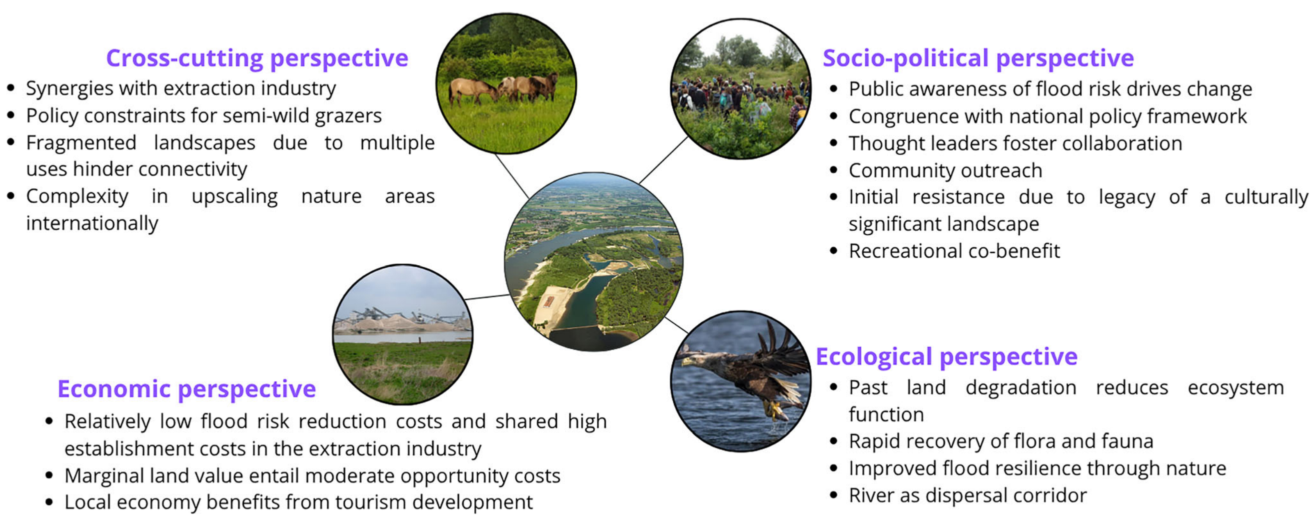

Fig. 4 Crucial factors for rewilding in the Gelderse Poort organised by four thematic clusters: (i) socio-political, (ii) ecological, (iii) economic, (iv) cross-cutting perspectives. The numbers assigned to each factor refer to the section in which the factor is described.
Photo credits: Sander Turnhout (top-right), Staatsbosbeheer (central), Nacho Villar (top-left), Wikimedia (bottom-left) and Bert Ooms (bottom-right)

12 000 people and losses amounting to 254 million guilders (approximately 115 million euros). Less than two years later, in 1995, a new flooding episode led to the evacuation of more than 250 000 people (Kolen and Helsloot 2014). These flooding episodes changed the perspective of Dutch society, which until then had assumed that civil

engineering projects such as polders and other barriers could protect them from high water levels. Instead, it was realised that a rethinking of water management was needed, in which branches of the Rhine and Meuse were to be given more space to drain water safely (Wolsink 2006).

This required landscape-level changes and a reallocation of land. The flooding events provided the urgency for such changes and encouraged social acceptance of land reallocation and redevelopment from agriculture to nature for the purpose of high water safety. Water safety is a top priority in the country and has been traditionally managed to protect against flooding (Brouwer and Van Ek 2004). A crisis or rapid change, such as a flooding event, can present a window of opportunity for transformation (Folke et al. 2011). Post-disaster moments have been shown to provide an opportunity for new forms of social organisation and governance to emerge (Pelling and Dill 2006), allowing for the adoption of a new management approach such as rewilding. Some authors have argued that such windows of opportunity are the critical factor to move from a preparatory phase of transformation to an actual transition, where the ability of recognising and capitalising on these moments for change is crucially dependent upon leadership capabilities (Olsson et al. 2006). In the case of Gelderse Poort, the floodings led to the emergence of a new type of paradigm of water management akin to rewilding and provided the urgency for people to more readily accept changes to the landscape. However, there are also cases where rewilding is not characterised by transformative change but rather driven by passive processes such as long-term land abandonment, that might not require a window of opportunity for realisation.

Core group of thought leaders and willingness to experiment

Key to the development of the Gelderse Poort has been the presence of a group of dedicated individuals with a collective vision, who led the ideas of what the landscape could look like. These people met at a time when a growing number of Dutch academics and nature conservation practitioners were experimenting with the notion that reintroducing large herbivores to nature reserves could bring back missing natural processes and boost biodiversity (Vera 2002; Vera et al. 2006). This was aligned with the emerging paradigm of trophic cascades and contemporary to the original concept of rewilding promoted by North American scholars on the other side of the Atlantic, albeit with a much stronger focus on the introduction of large grazers rather than top predators (Jepson et al. 2018).

Meanwhile, another group of rewilding pioneers and conservation NGOs elaborated a series of plans to experiment with nature development in river margins (“Plan Stork” and subsequently the “Living Rivers” concept).

As a small, well-connected and coordinated group of dedicated individuals, they were able to move rapidly. They also emphasised action over planning and monitoring, adjusting as they went along, so as not to delay its initial progress. They did, however, engage with the local communities from the beginning. This was done through organising educational excursions for school children in the area, involving local people to help remove fences and inviting local leaders to share the achievements of the area, such as releasing beavers or Konik horses. The absence of fences and creation of “struinnatuur” (nature where people are free to roam) was an important characteristic of the new landscape. These activities generated a sense of participation and ownership, and pride when realising that increasing numbers of tourists from around the world were visiting the area for its unique nature. This group of individuals has jointly carried the vision of the project for the decades which followed, allowing for a level of continuity and starting a network of collaborations with the National Forestry Agency, clay & sand extraction companies, WWF-Netherlands and NGO ARK Rewilding the Netherlands to refine the vision of the Gelderse Poort.

Synergies with sand and clay extraction companies to offset high initial investment costs

The rewilding of the Gelderse Poort required substantial upfront investments in land purchases and preparation. For example, a cost–benefit analysis (CBA) of upscaling the riverine rewilding highlights that achieving a naturally designed river system would require 35% higher investment than a business-as-usual approach for 46 km of river in a similar *Room for the river* region—the Midden-Waal (Ecorys 2021).

A key innovation for rewilding in the Gelderse Poort has been its funding model, reducing the costs. Public investments were partly offset through partnerships with resource extraction companies that mined clay and sand from the delta landscape (Fraccaroli et al. 2025). In exchange for mining permits, companies contributed directly to rewilding works in the floodplain and riverbed (Kok et al. 2025). Kok et al. (2021) describe this as an “in-kind contribution,” where private actors invest time and resources in return for rights to use certain co-benefits.

In Millingerwaard, the oldest rewilded area in the Gelderse Poort, the excavation and restoration of river dynamics would have cost about 20 million. Instead, collaboration with a resource extraction company generated 3 million in compensation for the state while enabling the sale of excavated sand and clay (personal communication, 2025). After resource extraction, the land was sold at a depreciated value to the National Forest Agency, making its regeneration to natural habitat more affordable. NGOs, such as WWF-Netherlands, played a central role in the 1990s in early agreements with brick-making companies (Jepson et al. 2018) and in fundraising for land acquisition (Luttik et al. 2006).

The moderate scale of mining, in small, fragmented patches and the visible return of nature helped reduce local resistance (Van Der Meulen et al. 2004). Still, the partnership depends on carefully and pragmatically balancing business interests with ecological goals: deeper excavation yields higher profits but reduces biodiversity compared to the shallow-water habitats (Damnjanović et al. 2019). Maintaining this balance relies on close collaboration, a willingness to compromise and strong trust among key stakeholders. This “business model for nature restoration” pioneered in the Millingerwaard has since been replicated across the Gelderse Poort and other Dutch floodplains. Furthermore, it has also been embedded in policy, with sand and clay mining permits now only granted when projects include significant nature development components.

Legacy of a culturally significant landscape

Legacy effects of previous land-use slowed down ecosystem reassembly in the Gelderse Poort. Agricultural practices left soils enriched with pesticides and fertilisers, potentially preventing the development of some ecosystem processes. While mining has contributed to create recreational areas in the past (including fluvial beaches), excavation sites were often used for illegal waste disposal. In addition, since only small fragments of late successional old riverine hardwood forest remained, the expectation was that without active restoration, forest expansion could require decades. Nevertheless, rapid natural regrowth of forests, including hardwood riparian species, is successfully ongoing without tree planting.

Cultural attachment to the previous landscape also generated initial resistance. Transforming traditional agricultural landscapes and water management provoked concern among local communities, after centuries of reclaiming land and “keeping water out”, especially as project ideas often came from external actors such as large NGOs (Brouwer and Van Ek 2004; Buijs 2009). The participative approach tried to address these fears; however, long-term residents expressed a sense of *“loss of the landscape of their childhood and the living environment as-they-once-knew-it”* (Bulkens et al. 2016, p. 9).

From an economic perspective, converting floodplain agricultural land implied opportunity costs, the foregone revenue of alternative land-uses, which might have been influenced by the higher land value due to the vicinity of urban areas (Le Coent et al. 2021). The higher flood risk, lower production capacity and water and soil pollution might have reduced these costs (de Jonge and van der Windt 2007; Brémond et al. 2013). As part of a larger government land reallocation plan, farmers were encouraged to exchange outer dike areas for inner dike agriculture areas further motivated by experiences of consecutive summer floods in the 1980s (Fraccaroli et al. 2025). Historically present brick industry and factories also had to relocate (Bulkens et al. 2016), implying some transaction and opportunity costs for the businesses and public authorities. Regulated mineral extraction continued in designated areas, supporting nature restoration through careful planning. Across these interventions, trust, dialogue, long-term relationships and the pursuit of mutual benefits among stakeholders were essential to manage the multi-use landscape and reconcile ecological, social and economic objectives.

Early successes and managing nature with large herbivores

A key element of rewilding in the Gelderse Poort is the reintroduction of semi-wild herbivores. In the beginning, mediatic reintroductions of charismatic species, such as Konik horses and Eurasian beaver caught the attention of the authorities and the general public, contributing to the visibility of the project. Beyond the media attention, these reintroductions of keystone species together with more natural flooding regimes resulted in a rapidly increasing biodiversity recovery in trees (e.g., black poplar), breeding birds (e.g., *Lanius collurio, Botaurus stellaris*), and pollinators (e.g., rare riverine butterflies), the comeback of many red-listed species, and a shift towards heterogeneous wildlife communities typical of floodplain ecosystems (Kursjens and Peters, 2012). These early successes also formed a proof-of-concept to people, highlighting that this vision of nature was feasible, a crucial factor in the success of rewilding projects in general (Weber Hertel and Luther 2023).

However, due to EU and national regulations for animal welfare and the dense human population and urbanised area, the maintenance of herds requires substantial financial resources for, e.g. vaccination of young calves and horses, genetic surveillance, control of population densities and transportation of surplus animals or supplementary feeding during the inundation periods (Bekhuis et al. 2005). Semi-wild grazers were initially introduced and managed by ARK Rewilding the Netherlands with support from WWF and the National Forest Agency, and are now overseen by FREE Nature, a foundation specialised in wild herbivore reintroduction. Their involvement re-distributed costs, responsibilities and risks, while ensuring management continuity. To control the stocking density of animals, surplus animals are either sold as "wilderness meat" or relocated to other grazing projects (Bekhuis et al. 2005). Business models involving the sales of meat once helped offset some of the costs, but are currently hindered by dioxin contamination from flood-deposited clay. Because of these regulations and limitations, managing these semi-wild grazers remains resource-intensive, highlighting the need for a sustainable financial model for herbivore management that balances ecological goals with economic demands.

Public co-benefits and a multi-functional landscape

As rewilding expanded, finding a balance between rewilding and other societal interests has been enabled by public co-benefits. Flood protection, a growing concern under climate change, has attracted public support and funding, enhancing the environmental and social values of rewilding (De Moel et al. 2011; Bulkens et al. 2016; Kok et al. 2025). In the northern Waard in the Gelderse Poort, rewilding reduced peak water levels by 10 cm, which is estimated to avoid 29.2 million in dike reinforcement costs between 2015 and 2075 (Ecorys 2021).

Aligning rewilding with flood protection can involve trade-offs. Ecologically valuable riverine forests—a rare ecotype in the Netherlands—would naturally develop in floodplains (Arens et al. 1998), yet water management authorities often see vegetation growth as reducing water-buffering capacity of floodplains during high water events (Berends et al. 2022). Similarly, growing river dunes might also affect flow resistance. In the Gelderse Poort, such issues are addressed by oversizing secondary channels to provide additional water retention.

In addition, over time, the Gelderse Poort has become an important recreational site for neighbouring urban centres, given its proximity to expanding cities such as Nijmegen and Arnhem. Nature development helped to meet the growing demand for outdoor recreation (Kok et al. 2025) thanks to non-use nature values and recreational value, resulting in increased visitation, boosting local eco-tourism and recreational services (van de Laar and Lycklama 2012). This recreational visitation of the site has enabled strong support for nature development (Buijs et al. 2004). Tourism growth created local jobs in hospitality and recreation, boosted accommodations sixfold between 1996 and 2010, with an annual expenditure of 6.3 million for outdoor recreation and accommodations and encouraged farmers to diversify into tourism (Luttik et al. 2006; van de Laar and Lycklama 2012). Access to green spaces likely enhances physical and mental well-being, potentially reducing healthcare costs in the long run and increases support for nature development in general (Christie et al. 2007; Shanahan et al. 2016; Coventry et al. 2021; de Kruiff et al. 2025b). Luttik et al. (2006) also suggest that house prices increased faster in the Gelderse Poort than in the surrounding areas. This happened in other parts of the Netherlands, where proximity to rewilded areas provides a 15% premium in house prices for close-by residential areas (Mutlu et al. 2023).

Location, scale and upscaling

The location and size of the Gelderse Poort have played a key role in its development, affecting it both positively and negatively. The rapid ecological development was facilitated by the connectedness to the river and rewilding of the flooding regimes. The river waters and riverbanks acted as dispersal corridors, connecting different areas and habitats, and possibly allowing species from upstream and downstream to colonise the rewilded areas, thus accelerating the comeback of flora and fauna. Furthermore, its most upstream location of the River Rhine in the Netherlands strategically feeds other flora and fauna populations downstream (Leyer 2006), and thus promotes biodiversity recovery across the Dutch Rhine.

However, the limited size, linear riverine structure and surrounding landscape constrain the connectivity of the rewilded area to other ecosystems, such as terrestrial broadleaved forests separated by arable fields, as well as its ecological processes and functions. Though some agri-environmental schemes have been applied in the surrounding agricultural area (Baumgarten and Aarts 2024), the migration of many species not targeted by these measures is still limited. In particular, large herbivores and omnivores, such as the absent red deer and wild boar, would add key complementary ecosystem functions to those provided by the larger cattle and horses. Furthermore, the agricultural barrier prevents the natural flow of nutrients, obstructing any potential buffering effects of these on ecosystem dynamics and resilience. Despite the highly heterogeneous habitats in the floodplains, biodiversity is constrained by the regulation of the density of free-roaming semi-wild populations and the absence of keystone apex predators such as the wolf. Nonetheless, white-tailed eagle and other raptors nest in the area, and many medium-sized mesopredators have colonised the area over the years (Waarneming 2022). These latter species, especially the white-tailed eagle, are symbolic and rare species in the Netherlands, and were a key policy objective in the initial plans for the rewilding of the area.

Scaling up the rewilded area is perhaps the most complex constraint. This would mean expanding the area into more productive lands, likely increasing costs, social conflicts and requiring cross-border policy and collaboration across the German border. As we have described, the project was made possible by a unique and timely combination of actors in a specific political context, which is difficult to replicate in new areas. Yet, some of the factors that contributed to the transformative success of Gelderse Poort can be applied in other locations and contexts.

LESSONS AND OPPORTUNITIES FOR TRANSFORMATIVE CHANGE AND UPSCALING OF REWILDING IN EUROPE

The aim of this paper was to conceptualise characteristics that determine the transformative change potential of climate-smart rewilding, building on Gelderse Poort as an illustrative case study. To address the twin crises of biodiversity loss and climate change, we need fundamental and rapid transformative change across our society. Policies that are incremental in their nature, or do not disrupt the status quo, are unlikely to scale sufficiently or are too slow to structurally create the necessary change (Pascual et al. 2022). In the case of rewilding in the Gelderse Poort, the crucial factors that shaped the development of rewilding converge in multiple elements of transformative change. Based on this case study, these elements can serve as essential lessons for inspiring and upscaling transformative change in other rewilding projects at landscape and regional scale in Europe and elsewhere. These elements and lessons are summarised in Table 1.

First, the paradigm shift of river protection in the Gelderse Poort, working with, instead of against nature, provided the room for natural processes to return to the landscape. In practice, this involved restoring natural hydrological dynamics, reconnecting rivers with their floodplains, and allowing ecological processes such as flooding, sediment transport, and grazing to shape the landscape rather than relying solely on hard infrastructure that may lock-in risk. Capitalising on the window of opportunity after major flooding events paved the way for public acceptance of new solutions, demonstrating a systemic, path-shifting vision encompassing comprehensive shifts in urban planning and flood protection, as well as a vision break from the status quo (Tábara et al. 2018; Pal et al. 2019). Here, the lower costs and reduced risk of the nature-based solution of rewilding contributed to make "room for the river" an attractive option. In this sense, other public co-benefits, in this case flood risk reduction, were leveraged as a motor for nature development.

Our case illustrates how such a shift can unfold in practice. In the Gelderse Poort, shifting the paradigm to work with nature as a climate-smart solution to societal challenges led to radically different scenarios that have a co-benefit of nature recovery while rendering climate change adaptation and mitigation outcomes. For example, giving room for the river and the sea in areas with high flood risks, such as river Deltas or coastal areas in other European regions and elsewhere can help to prevent flooding while allowing nature recovery, improving

Table 1 Overview of transformative change and lessons learned in Gelderse Poort for upscaling climate-smart rewilding projects

Broader challenge in climate change mitigation and adaptation and nature conservation and restoration	Business-as-usual alternatives	Transformative change in Gelderse Poort	Lessons learned for upscaling climate-smart rewilding in Europe
Coping with extreme events caused by climate change	Hard flood defence infrastructure in the form of dikes and groynes	Shift to nature-based restoration of river–floodplain dynamics within Room for the River using post-flood windows for systemic change	Mainstream "work with nature" allowing natural processes into local and regional planning
Biodiversity loss under climate change	Management approach based on very specific and static compositional or habitat targets	Shift to a process-based, open-ended approach to nature restoration	Recognise and accept uncertainty in restoration outcomes to create new nature based on functional principles
Shortage of funding for nature restoration and conservation	Public and NGO funding	Development of public–private partnership model to mobilise private sector funding for rewilding	Leverage and institutionalise public–private investments and partnership to redistribute costs and benefits
Lack of public support for nature restoration and conservation initiatives	Top-down institutional landscape planning and compensation without direct community involvement	Continuous and early involvement of and outreach to nearby communities, experts and citizens in general	Adopt long-term participatory governance for design and implementation of climate-smart rewilding initiatives
Limited integration of nature in urban environments	Separation of nature and urban in the landscape	Integration of nature within peri-urban landscapes for recreational access, flood risk reduction, tourism development and other mutual co-benefits	Integrate climate-smart rewilding into urban planning for social co-benefits

climate resilience. While this principle is illustrated by the Gelderse Poort case, similar approaches are discussed in the broader rewilding and nature-based solutions literature as a way to enhance ecosystem adaptability under uncertain climate futures. This includes for example the creation of "sponge" landscapes with high water retention capacity, such as wetlands or bogs, and through the restoration of natural hydrology dynamics (Opperman and Galloway 2022). Wetland and peatland restoration projects across Europe show how re-meandering rivers, rewetting degraded peatlands and restoring floodplain wetlands can simultaneously store water, buffer floods and droughts, enhance biodiversity and contribute to climate mitigation via increased carbon storage (Tanneberger et al. 2021). Beyond aquatic and semiaquatic ecosystems, these experiences point to the need to mainstream "working *with nature"* principles instead of *against nature* into local and regional spatial planning to cope with climate change. In a meta-analysis of rewilding, ecosystems' responses to disturbances such as invasive species, droughts and fires improved in around 70% of the cases (Selwyn et al. 2025). Particularly effective strategies include the reintroduction of large herbivores to curb invasive plants and the use of prescribed burns to favour more fire-resilient species (Rouet-Leduc et al. 2021; Selwyn et al. 2025).

Second, instead of protecting existing landscapes, rewilding in the Gelderse Poort focused on creating new habitats as a way to increase biodiversity, embracing an open-ended outcome guided by a functional rather than a compositional restoration approach. This new nature provided space to adopt a novel approach that focuses on natural processes as a target without aiming at a specific baseline condition and balancing the role of humans with nature. Despite being grounded in ecological principles, this approach requires the acceptance of some level of uncertainty about the outcome state, making it future-oriented and adaptive to evolving ecological processes (Scolobig et al. 2023). The approach adopted in the Gelderse could be upscaled across Europe and elsewhere by focusing on natural processes as a reference instead of being constrained to protecting the existing habitats or returning to a specific baseline. This can either lead to creating new nature, or it can also be applied to existing natural areas, including protected areas that are steered towards specific compositional and habitat targets.

A third transformative element is the partnership model, where stakeholders were willing to work across traditional divides to bring about change. This diffusion of governance, referred to as "polycentric institutions", involves the revision of mandates and responsibilities beyond the initial intervention, thereby fostering co-benefits and innovation (Fedele et al. 2019). In the Gelderse Poort, this polycentric approach took shape through a partnership between clay mining and nature development. More broadly, engagement with unlikely allies for nature development can be formalised and scaled to provide an opportunity to institutionalise and scale up rewilding, as well as distribute the high establishment costs between public and private stakeholders. This is region and context-dependent and requires a thorough assessment of the economic-nature restoration model, but the willingness to embrace private companies as partners offers myriad possibilities for mobilising capital towards climate-smart rewilding. This includes access to funding streams dedicated to climate change adaptation, biodiversity restoration or ecosystem services, facilitating the upscaling of climate-smart rewilding initiatives.

Fourth, the Gelderse Poort stakeholders also re-envisioned the way people connect with nature. From the start, stakeholders were engaged and involved through several activities, including field work classes for primary school children. The co-creation of the practical implementation of rewilding in the Gelderse Poort through early and sustained involvement of experts and local, regional and national stakeholders facilitated its broader acceptance and accelerated its development. Rather than excluding people from the landscape, this approach includes people as part of the rewilding approach. This participatory model reflects a broader "zeitgeist" in environmental governance: a shift towards inclusive, collaborative, and place-based approaches that challenge top-down conservation paradigms (Keulartz 2009). Co-creation is already a mainstream approach to decision-making and innovation (Matarrita-Cascante et al. 2019), and our findings from Gelderse Poort suggest that upscaling of rewilding at the European level can be more successful when embedded in such inclusive participatory frameworks from the beginning of the rewilding process (Scolobig et al. 2023). Similarly, in the Oder Delta, the presence of trusted NGOs, participatory approaches and long-term relationships among diverse actors enabled rewilding (Massenberg et al. 2026). Moreover, the lesson of incorporating recreational access to create a connection with the landscape could help in different areas of Europe to build support for rewilding.

As a final element of transformative change, the Gelderse Poort is an example of an ecosystem restoration that embraces and integrates nature in a human-dominated landscape, a change in thinking in depth (Biesbroek et al. 2026). In traditional thinking, it is frequently assumed that nature needs to be far away from the urban centres and requires large areas of land. The Gelderse Poort highlights that a relatively small area connected with the city can be beneficial to both ecology and economy. It shows that rewilding of (peri)urban areas is possible in human-dominated landscapes, even if it involves large herbivores and natural disturbance regimes. The implementation close to a population centre results in great benefits in terms of creating recreational opportunities and reconnecting an urban population with nature. The Gelderse Poort can provide inspiration for potential application in other (peri)urban environments across Europe and beyond. This shift in thinking allows for more sites to be considered viable for ecosystem restoration in urban and peri-urban planning, where it can deliver social co-benefits such as recreation, health and cultural values along with ecological restoration.

The above shows how climate-smart rewilding has transformed the Gelderse Poort area in a systemic manner, changing the paradigm of management in its structure, collective thinking patterns and organisation. These changes have proven to be sustainable over the last decades and cascaded into a wider Dutch policy landscape, having been embedded into and inspired policy as part of the Room for the River programme, integrating flood adaptation with biodiversity recovery in the Dutch delta (Straatsma et al. 2017). Several of the above elements correspond to the guiding principles of rewilding of Carver et al. (2021), such as the embracement of open-ended outcomes and the participatory and inclusive approach. In the Gelderse Poort, these are explicitly mobilised to deliver climate-risk reduction and co-benefits for society. Overall, the Gelderse Poort serves as a pioneering case study of climate-smart rewilding, a priori unlikely in a peri-urban, human-dominated landscape, exemplifying how climate-smart rewilding can address multiple societal challenges when embedded in broader adaptation and development strategies.

Several of the identified elements in Gelderse Poort correspond to principles discussed more broadly in the rewilding and nature-based solutions literature (Fedele et al. 2019; Pascual et al. 2022; Massenberg et al. 2026). In this sense, Gelderse Poort illustrates how these principles can interact in practice to produce climate adaptation and mitigation benefits under specific socio-ecological conditions. At larger spatial scales, these principles need to be embedded in river-basin, regional and national planning processes if climate-smart rewilding is to move beyond isolated flagship sites. Building on this, we argue that climate-smart rewilding represents a broader transformative shift in how the intertwined crises of biodiversity loss and climate change are addressed, by deliberately harnessing nature's potential for both climate change mitigation and adaptation while delivering societal benefits (Stark et al. 2025). Beyond individual projects, upscaling climate-smart rewilding will require structural integration into climate change adaptation, disaster risk reduction and nature-restoration policies (e.g. EU Adaptation Strategy, EU Nature Restoration Law). This should be done in ways that consider multiple processes and objectives, as well as make strategic use of emerging opportunities for conservation and ecosystem restoration such as farmland abandonment or declining agricultural productivity (Stark et al. 2025). Embedding rewilding within policies addressing flood and fire management, drought resilience and biodiversity recovery are essential for upscaling. This also requires designing financing and governance instruments that reward different ecosystem services, from biodiversity, carbon and risk-reduction benefits. In practice, this can include innovative public–private partnerships that mobilise private capital for landscape redesign and long-term management. Together, these measures can create enabling conditions for the replication and scaling of climate-smart rewilding initiatives in human-dominated and peri-urban contexts, while also enhancing societal co-benefits.

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