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Social-ecological perspective on European semi-natural grassland conservation and restoration: Key challenges and future pathways

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ABSTRACT

Semi-natural grasslands result from traditional agriculture and are among the most species-rich ecosystems in Europe. These grasslands were once widespread across Europe, but due to changing agricultural practices, only small remnants have remained until present day. Large-scale efforts to preserve and restore these valuable ecosystems encompass the continuation or reintroduction of extensive instead of intensive farming practices. Based on empirical insights from three regions in Estonia, Germany and Spain, we aim to highlight *Profitability*, *Landscape-scale Trade-off and Lock-in Effects*, *Policy Fit & Interplay*, *Changing Rural Societies* and *Climate Change* as being five common key challenges making such efforts difficult. We suggest three general pathways to leverage changes: A) emphasize a *social-ecological perspective at the landscape scale* where both traditional and new framings of extensive farming practices are constructed in accordance with local contexts; B) work towards *a wider ecosystem service perspective of semi-natural grasslands.* This involves shifting the perspective on grasslands from being agricultural "wastelands" to not only acknowledge their biodiversity, but also their role as cornerstones of resilient agricultural landscapes; and C) embrace *experimental learning and policy alignment* at the regional scale to better embed extensive farming practices in European land use polices. Policies and administrative practices should be adjusted to account for vastly different conditions across and within regions, where extensive farming practices are sometimes integrated into large-scale agricultural enterprises, and sometimes carried out as a non-commercial side activity at a very small-scale.

1. Introduction

Biodiversity in Europe is closely linked to cultural landscapes. Traditional agriculture led to high biodiversity by establishing a small-scale mosaic of different extensively managed land use types (Robinson and Sutherland, 2002). Semi-natural grasslands on dry and nutrient-poor soils (Kasari et al., 2016; Öckinger et al., 2006) are known to be one of the most species-rich habitats in Europe (Dengler et al., 2014) and offer niches for many endangered species, including plants, insects and birds (Ernst et al., 2017; Fartmann, 2024; Gazol et al., 2012; Kormann et al., 2015). In addition to their high conservation value, these grasslands also provide a range of wider ecosystem services, which include the provision of fodder, erosion control, carbon sequestration, support in water regulation and landscape aesthetics (Prangel et al., 2023; Zhao et al., 2020).

Biodiversity of temperate grasslands has originally developed with wild ungulates. These grasslands, and their biodiversity, were then extended and maintained mainly by transhumant shepherding on a large scale in combination with other traditional land use practices (e.g., hay production), which experienced significant growth during the fourteenth and fifteenth centuries in Central Europe (Pärtel et al., 2005). The loss of these grasslands then mainly started at the end of the nineteenth century due to the conversion of grasslands into arable land, afforestation and grassland abandonment (Fartmann, 2024; Pärtel et al., 2005).

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The farming business in Europe had been forced to concentrate their financial resources and working time on productive land and farming practices to maximize revenues from the available land in Europe over the last century (Chang, 2012). This led to a transition from extensive to intensive agriculture and the increasing use of high-performance cattle, which are less suitable to graze on the fibrous hay grown in nutrient-poor semi-natural grasslands (Poschlod and WallisDeVries, 2002). Today, only small remnants of the previously vast semi-natural grassland areas are left within European landscapes that are dominated by intensively managed arable fields and forests (Calaciura and Spinelli, 2008; Fartmann, 2024; Poniatowski et al., 2018). Large-scale efforts to conserve and reestablish these valuable habitats are urgently needed (Jones et al., 2018; Samways et al., 2020).

Because of their high species diversity, semi-natural grasslands in Europe have been model ecosystems for a wide range of empirical and theoretical ecological studies (Dengler et al., 2014; Helm et al., 2006; Öckinger et al., 2006; Pärtel and Zobel, 1999; Poschlod et al., 1998; Reitalu et al., 2014). This has led to a relatively good understanding of ecological and landscape-scale processes influencing their biodiversity. Moreover, recent research has made important advances to support conservation practice by focusing on ecological effects of site-level management. Török et al. (2021) offer a very useful recent compilation of distinct site-level management strategies that enhance biodiversity in semi-natural grasslands by reviewing empirical outcomes. Although site-level management could take many different forms, conservation and restoration efforts encompass the continuation or reintroduction of extensive farming practices in the form of grazing and/or hay production to ensure high biodiversity across different trophic levels (Ernst et al., 2017; Gazol et al., 2012; Kormann et al., 2015; Neff et al., 2020).

This study focuses on contextual social-ecological factors, which determine whether (or not) effective site-level management strategies *can* be applied and maintained over time. So far, a synthesis of such factors that goes beyond the intricacies of site-level management, and across different social-ecological contexts in Europe, is missing. We fill this gap with the aim to identify key challenges to the management and restoration of semi-natural grasslands. The identified challenges are exemplified based on insights from three regions in Estonia, Germany and Spain. We then discuss pathways derived from good practice examples in these regions for improving the management and restoration.

2. Methods

The geographical focus for our study were three well studied empirical case regions in Estonia, Germany and Spain (Fig. 1). The three regions represent different cases for European semi-natural grassland conservation contexts. Differences of these contexts include, for instance, the trend of nationwide coverage of semi-natural grasslands (Estonia slightly increasing coverage; Spain and Germany decreasing), size of existing patches (Estonia larger patches, Germany small patches, Spain both), climate zones (Estonia Hemi-Boreal Climate Zone, Germany Temperate Climate Zone, Spain Mediterranean Climate Zone) and socio-economic contexts (see next section). For more information on the study regions see Table 1.

Our research approach builds on utilizing three different methods in combination. The methods include literature review, qualitative interviews with key stakeholders in the study regions and expert knowledge elicitation. Firstly, we conducted a review of relevant academic literature, and assessed available non-published data as well as local to international policy documents. This review included conservation

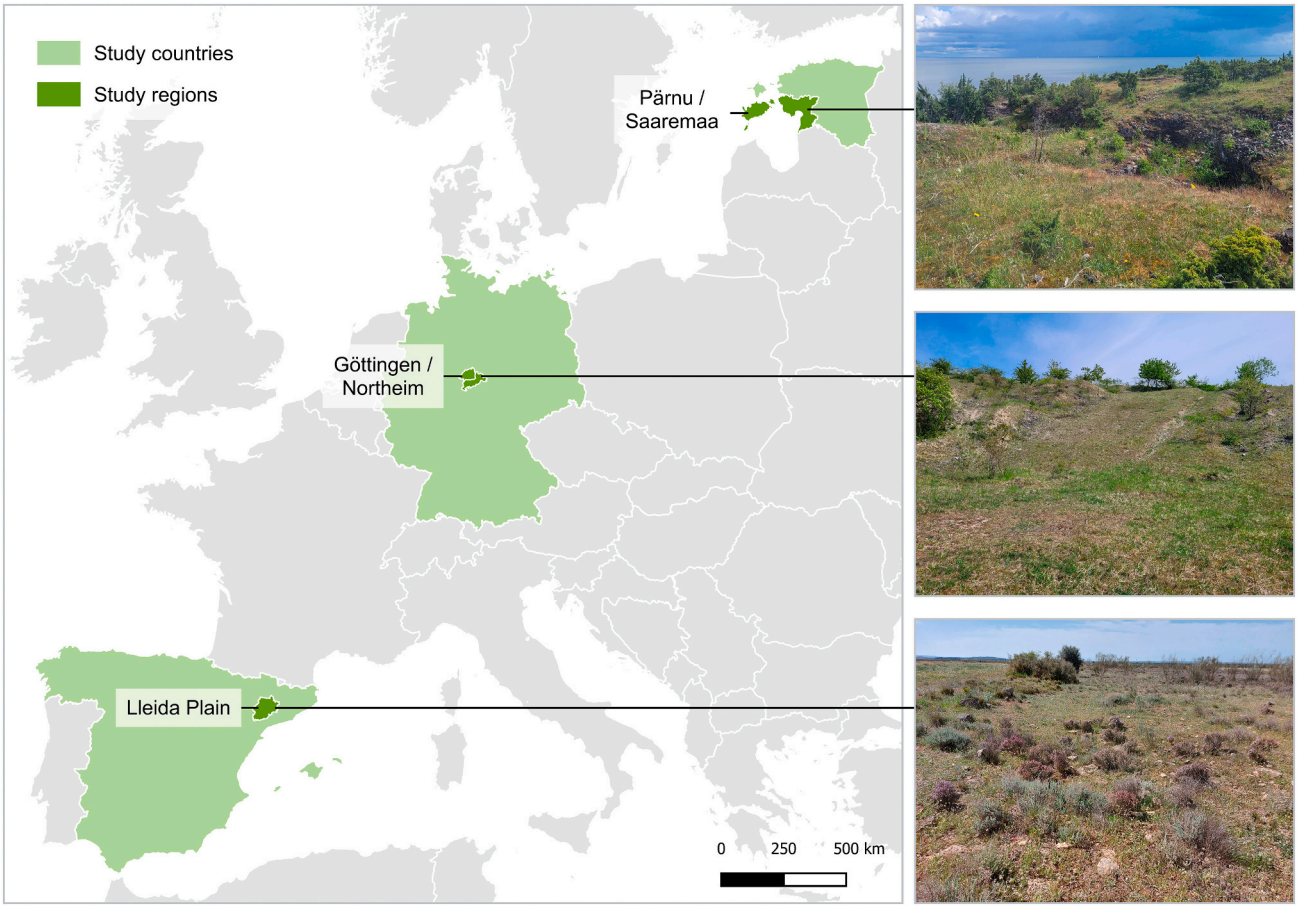

Fig. 1. Map of the study regions and photos of semi-natural grassland sites in Estonia, Germany and Spain. Photos by P. Gorris & X. Cabodevilla.

Table 1
Descriptions of the semi-natural grasslands in the case study regions. Habitat codes refer to the EUNIS classification of European habitat types (Davies et al., 2004).

Country	Study region	Context
Estonia	Western mainland and the Baltic islands Muhu and Saaremaa	Calcareous grasslands (habitat code 6210, 6280) in Estonia are concentrated in the northern and western part of the country. The study region is in the hemi-boreal climate zone with relatively large calcareous grassland patches; often one pasture includes semi-natural grasslands of different habitat types. The study area with its 11 % semi-natural grasslands (ca. 1/3 managed) has a higher cover than the rest of Estonia. Semi-natural grasslands are embedded in forests and agricultural land. All managed study sites in the region are located in nature reserves. The grasslands in the area are mainly grazed by sheep, goats, cows, and occasionally horses and sheep. After the large-scale decline in grassland area until the end of the 20th century, nationwide semi-natural grassland restoration efforts over the past 15 years have led to a slow but steady increase in overall semi-natural grassland coverage, incl. calcareous grasslands coverage in the study region.
Germany	Central Germany, Southern Lower Saxony in the districts Goettingen and Northeim	Calcareous grasslands (habitat code 6210) are widespread in Germany, but most common in central and southern Germany. The study region is located within temperate latitudes in the transitional area between oceanic and continental areas. Land use in the study region is dominated by intensive crop farming with cereals, oilseed rape, maize and sugar beet as main crops. Hilltops are often covered with fertile grasslands and forest patches. The majority of calcareous grassland patches in the study region are smaller than 1 ha; only few larger sites exist. The grasslands in the area are mainly grazed by horses, goats and sheep, but also sometimes cows. The percentage cover in the study region was estimated to be 0.26 % twenty years ago and the small sites are widely dispersed. No data is available for today, but coverage might have further declined. With few exceptions, almost all sites in the study region were in a state of succession at some time over the last decades and had been restored mostly based on local small-scale initiatives (environmental NGOs).
Spain	Northern Spain, Catalonia, at low altitudes south of the Pyrenees in the Lleida Plain	Calcareous grasslands (habitat code 6210, 6220) in Spain are found in the Mediterranean, Atlantic and alpine bioregions. Our study area is part of the Mediterranean Bioregion just south of the Pyrenees area. Calcareous grasslands exist there as usually small (ca. 0.5–20 ha), but sometimes still some large patches (ca. 1000 ha), usually dispersed across cropped areas (esp. cereal, almonds and olive trees) at lower altitudes (e.g., in the Lleida Plain).

Table 1 (*continued*)

Country	Study region	Context
		The grasslands in the area are mainly grazed by goats and sheep, and to a lesser extent by goats. The situation of calcareous grasslands in the study region follows the countrywide trend of decreasing coverage and increasing semi-natural grassland ecosystem degradation. Few conservation and/or restoration initiatives exist with regards to semi-natural grassland ecosystem nationwide and in the study region.

legislations at the EU-level (such as CAP, NATURA2000, Habitat-Directive etc.), national level conservation legislation in the respective countries as well as local rules that specify grassland management action and compensation schemes in the study regions. The authors contributing to this study have different disciplinary backgrounds and reviewed scientific publications on social-economic and ecological challenges for European semi-natural grassland management from their respective field of expertise. Authors from each of the regions reviewed the local, regional and national policy documents as well as grey literature available for the study areas in the local languages Spanish, Catalan, Estonian and German.

Secondly, we conducted a total of 14 qualitative semi-structured interviews (ca. one hour each) (for details on the methods see e.g., Bernard, 2006) with conservation managers and farmers in Estonia (3 interviews), Spain (5 interviews) and Germany (6 interviews) in 2022/23 to include the expertise and perspectives of non-academic stakeholders. The interviews were conducted by experienced scientists from the regions. The interview guidelines and information on the interview partners from each country are included in the Supplemental Material. The interviews were transcribed, but not formally coded. Instead, the interviews were discussed and interpreted collectively, as well as individually, by the teams of researchers in each study region, respectively. The interviews provided valuable qualitative data sources, which allowed rich insights into context-sensitive practical socio-ecological challenges and potential pathways to address these challenges.

Lastly, we used an expert knowledge elicitation approach to bring together different regional and academic discipline-specific expertise to identify factors facilitating and hindering effective management of semi-natural grasslands. In different forms, this methodological approach has been used in various fields of natural resources management studies (cf., Huang et al., 2021; Perera et al., 2012) and other environmental sustainability-related research (cf., Chrysafi et al., 2022; Morgan, 2014; Runge et al., 2011). In our case, we drew on the knowledge of our highly diverse interdisciplinary author team from different social and natural science disciplines with several years of extensive research experiences in the study regions. We carried out a regular systematic exchange in an open process with the aim to identify challenges for semi-natural grassland management and potential pathways to address these challenges in our study regions. Regular online meetings over more than 18 months in 2022–2024 and a presential workshop in Spain in March 2023 were held for this purpose. The meetings served to present and discuss the results of the interviews, literature reviews and our scientific experience from the regions. The challenges and potential pathways to address these challenges presented in these meetings were interestingly similar for each region. We clustered the insights into thematic categories as common themes emerged quickly. Each regional team then collected region-specific examples, quotes from their interview material and references (where available) for each of the categories. A small number of examples, some quotes (i.e., the most fitting) and references were then selected to be included in the article to illustrate the identified challenges and pathways.

Consequently, the underlying research approach is explorative and is based on an in-depth understanding of the relevant literature combined with the authors' knowledge of the empirical case studies as well as on the insights obtained from the interviews with key stakeholders. We focused on species-rich semi-natural calcareous grasslands in our study regions, but all identified challenges apply to a wide range of different semi-natural grassland types across Europe.

3. Results and discussion

3.1. Key challenges

We identify five key challenges for semi-natural grassland restoration and conservation ranging from environmental and economic to societal and political challenges. These challenges are presented in Fig. 2 (incl. the pathways described in Section 4) and are summarized in Table 2. The challenges are described in more detail and contextualized based on concrete examples from the three study regions in the following sub-sections.

3.1.1. Profitability

Semi-natural grasslands have in general lower productivity than other grasslands (Assaf et al., 2011). Today, despite being strongly subsidized through local, national and EU measures, extensive farming based on semi-natural grasslands is economically difficult. The west of Estonia, for instance, is still covered by larger areas of connected semi-natural grasslands. Yet, insights from our study region show that only the management of relatively large areas of these grasslands generates sufficient profit to make a living based on extensive animal farming. Still, farmers in such cases often have other income sources besides extensive animal husbandry, such as tourism (Interview EST2) or day-jobs elsewhere (Interview EST3). Moreover, insights from the region also show that such large-scale profit-oriented extensive animal farming may lead to different attitudes towards the management of semi-natural grasslands due to economic pressures (e.g., these areas are more prone to overgrazing) (Interview EST3). A specific challenge is that locally produced meat from semi-natural grasslands is more expensive and consumers usually do not (and often cannot) distinguish between differently produced beef (Interview EST2). It would take special marketing efforts to communicate the added value of semi-natural grassland products, which is beyond the reach of individual farmers.

In regions with only smaller continuous semi-natural grassland

Table 2
Descriptions of key challenges for grassland management and examples from the study regions in Estonia (EST), Germany (GER) and Spain (SP).

Challenge	Description	Examples
Profitability	Extensive agriculture based on grazing and hay production is key for semi-natural grassland biodiversity, but is becoming increasingly unprofitable across Europe.	Meat produced on semi-natural grasslands with low grazing intensity is more expensive [GER, SP, EST] Market share of products from goats and sheep decreases [GER, SP, EST]
Trade-off and lock-in effects	Multiple interdependent use forms (food production, forestry, species conservation, infrastructure development etc.) compete with each other producing lock-in effects and sectoral trade-offs at the landscape scale.	Grasslands are converted into arable land or forest [GER, SP, EST] Grassland conservation clashes with protection of wolves [GER]
Policy fit and interplay	Sectoral policies at multiple levels in the political system impact grassland conservation and restoration, which creates mis-fits and often fail to capitalize on potential synergies.	Regulations to obtain subsidies are not well aligned with extensive husbandry practice [GER, SP, EST] Administration produces high bureaucratic workload for farmers [GER, EST]
Climate change	The regional effects of climate change have important social, economic and ecological consequences for semi-natural grassland management.	Animals need additional food and water during draughts [GER, SP, EST] Range shifts of predators occur [EST]
Changing rural societies	Depopulation, population aging, lack of attention to its importance by society and economic marginalization in rural areas complicate extensive animal farming.	Drop-out of older extensive farmers leads to decreasing workforce and local knowledge [GER, SP, EST] Loss of local service providers (e.g., shearers, wool processors) make extensive husbandry more difficult [GER, SP, EST]

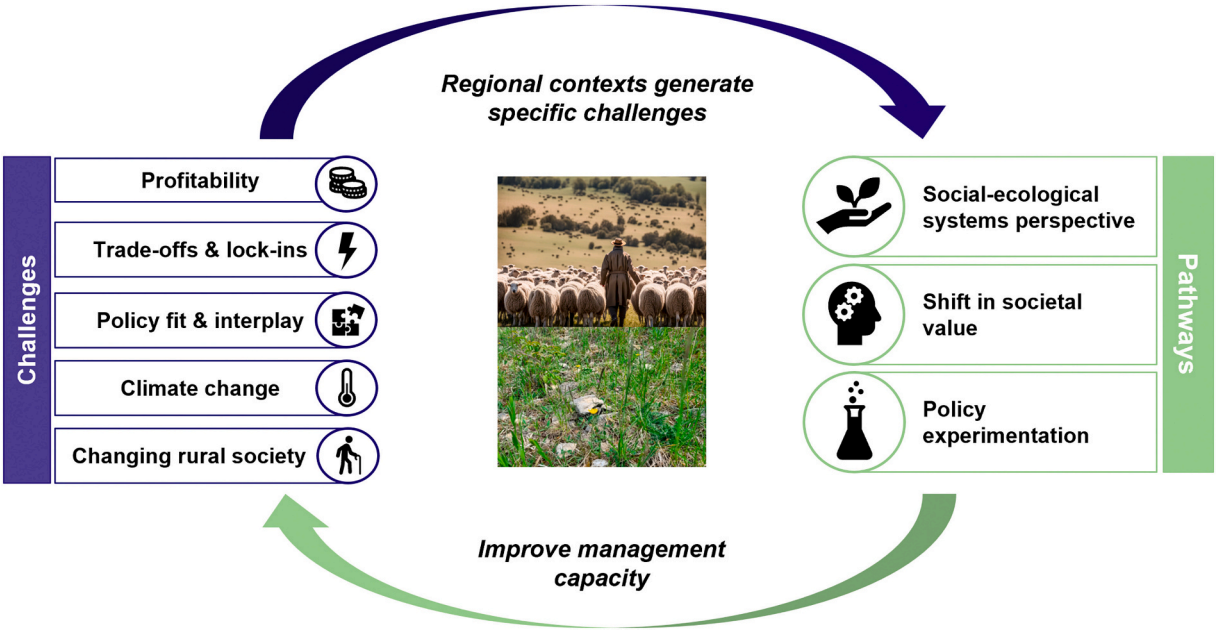

Fig. 2. General challenges that are common to restoration and conservation of European semi-natural grasslands. Regional contexts control and modify the region-specific impacts of these challenges. The three pathways help to improve semi-natural grassland management capacity, if they are regionally adapted and combined.

areas, farmers involved in extensive animal farming (esp., of goat and sheep) heavily struggle to make a living from this business. In our German study area, for instance, semi-natural grassland managers can receive subsidies related to grazing based on Agri-Environmental Schemes (AES) in addition to the basic per hectare premium under the Common Agricultural Policy (CAP). Moreover, the lease on local state-owned land is usually remitted and additional local subsidies are paid in the study area, which include an annual premium for each sheep and goat. However, asked to estimate the hourly wage for extensive grazing on semi-natural grasslands, an interviewee responds "*Well, it takes a few hours. But in the end, I don't even want to know how many hours. If you calculate the hourly wage…* [*laughs out loud*]*… It's definitely in the minus range!*" (Interview GER-IGO1). In addition, current increases in input prices (e.g., fuel, fodder) add to the problem. This leads to the widespread situation in the German region that one informant describes as follows: "*With the price of diesel, driving up there every day … and the hours worked … and the animals. I can't put high-performance animals on it. So that's actually unfortunately almost only a hobby.*" (Interview GER-IGO1). In Catalonia (Spain), the situation is very similar. A respondent noted that "*We have been in the sheep sector for quite some time, and the economic profitability is now very low.*" (Interview SP1). Extensively managed herds are consequently quickly disappearing. In Germany, for instance, the number of sheep dropped by more than 50 % between 1990 and 2020 from 3.24 to 1.48 million animals (Statista, 2024).

Yet, insights from our study region in Germany also show that profit is typically not the main reason motivating persons to engage in extensive grazing of semi-natural grasslands, although these motives may not compensate for negative gains over longer time frames. For example, one respondent in Germany explains regarding his motivation that "*These* [*add.: calcareous grasslands*] *are the hotspots of biodiversity in the region. If you look for endangered vascular plant species, for example, you will find up to 30 endangered species on a single site of calcareous grassland. You can map 100 hectares of intensive grassland and find 1-2 of them.* […] *Then you say okay, this is worth the effort; this is something very special.*" (Interview GER-IGO-CS1). Moreover, another informant states that "(…) *it's nice when you walk across the grassland and look for the animals, because they've somehow hidden in a bush and they're happy. Then that makes me happy too*" (Interview GER-IGO1). These statements emphasize the importance of an additional emotional "reward"-system, which is based on strong attachment with nature, or simply the joy of being engaged in animal husbandry as a hobby. These farmers often have smaller numbers of grazing animals and engage in grassland management as a side activity for non-profit oriented reasons and, for the most part, sustain their living from other income sources (e.g., working in non-farming jobs, couple their farming activities with tourism etc.). Whether this aspect also plays an important role in other European regions warrants closer examination in future research.

This shows, that albeit already heavily subsidized, extensive forms of managing semi-natural grasslands are hardly economically viable and the number of grazing animals is dropping. Only in areas with large connected grasslands, such as in our study region in Estonia, can low intensity grazing in semi-natural grasslands provide enough revenue to sustain a living. Importantly, this study shows that new actors in grassland management have emerged in Germany (and possibly elsewhere), who are non-commercial grazing animal holders. This development seems to be most pronounced where only small patches of semi-natural grasslands remain in the wider agricultural landscape.

3.1.2. Trade-offs and lock-in effects

Most European agricultural landscapes serve multiple interdependent purposes including food production, forestry, species conservation, settlements and different forms of tourism (Neyret et al., 2023). Many of the purposes the landscape is used for, produce (inter-)sectoral trade-offs and lock-in effects (examples are given below). This has important social-ecological implications for semi-natural grassland conservation and restoration.

In the German and Catalonian study region, for instance, most of the semi-natural grassland was converted into arable land or more productive grasslands used for intensive grazing. This development has had a considerable lock-in effect; i.e., it is highly difficult to reverse the changes. Once land has arable status in the agricultural system, convincing farmers to turn it back into extensively used semi-natural grassland is a big challenge and, as a consequence of intensive land use (i.e., the application of fertilizer), often ecologically difficult (Conrad and Tischew, 2011; Fagan et al., 2008; Kiehl et al., 2006). Similarly, in the Estonian study region, grassland areas have been used for afforestation with similar lock-in effects, because restoration of grasslands overgrown with forest requires heavy machinery and massive effort to restore high grassland biodiversity. These locked-in land cover conversions led to the increasing reduction of semi-natural grassland habitats in many cultural landscapes across Europe with severe ecological consequences, because semi-natural grassland loss leads to increasing habitat fragmentation with detrimental effects on biodiversity (Gámez-Virués et al., 2015; Grass et al., 2018; Kormann et al., 2015; Lane et al., 2020; Pellissier et al., 2018; Perring et al., 2015). This may cause a considerable extinction debt – i.e., a situation in which species are no longer supported by the surrounding landscape structure (Helm et al., 2006; Löffler et al., 2020).

Fragmentation resulting from locked-in land cover conversion of semi-natural grasslands also has implications for grazing animal holders. A specific practical challenge is site accessibility. In the German region, small sites are spread across the wider landscape. Particularly, in remote places these sites are often abandoned, because no extensive animal farmer has the capacity to maintain them, due to high financial and time effort needed for management. A farmer in Germany puts this as follows: "*The sites are scattered everywhere. The management has become so expensive just by driving around. You have to go and look in each site every one or two days and bring water to the animals*" (Interview GER-IGO-CS1). Another farmer states that "*What also makes it difficult are all the small areas. Some of them are maybe 0.2 hectares or so.*" (Interview GER-IGO1) or "*And I then move around practically in the whole area all year round and do area hopping*" (Interview GER-IGO2). Therefore, in addition to ecological connectivity problems of land cover conversions, a further concrete challenge for practical management is that the resultant fragmentation of semi-natural grasslands significantly increases the amount of time, effort and financial resources necessary for management.

Antagonistic effects (i.e., trade-offs) between different uses in a landscape exist beyond the direct competition for land and the spatial arrangement of land uses. For instance, the conservation of iconic species, such as the wolf, frequently clashes with the biodiversity conservation in semi-natural grasslands. Wolves are a protected species in Europe and the relatively mobile populations are recovering across the continent (Pettersson et al., 2021), which is widely known to have caused conflicts in many rural areas (Zscheischler and Friedrich, 2022). A German respondent stated in this regard that "*I got wolf protection nets, the handling is super difficult in the terrain. And it costs extra*" (Interview GER-AB). Another German farmer stated that "(…) *as an animal keeper, the welfare of the animals is very close to your heart, if you then see some cases where the animals are killed by wolves. Hunted! That hurts you! And that will scare off many grazing animal owners, who no longer do that*" (Interview GER-JR). In the context of semi-natural grassland management, the presence of the protected wolf presents a significant emotional and practical challenge.

Thus, past and ongoing landcover changes at the scale of the landscape produce lock-in effects and come with severe ecological as well as socio-economic implications, such as fragmentation of semi-natural grasslands, which are difficult to reverse. Furthermore, this section exemplifies how trade-offs between different uses of the wider landscape complicate extensive agricultural practices needed for effective restoration and conservation efforts.

3.1.3. Policy fit and interplay

Policies affecting the management of semi-natural grasslands are found across multiple administrative levels in the political system and span a variety of sectors. The specific policy design has to fit local practices and contexts to be effective. Moreover, different sectors usually each have a legacy of historically evolved roles and responsibilities among different governmental authorities across the political system and self-organizing non-state actors (Young, 2002). The effectiveness of policies often depends not only on their own features, but also on their interactions with other policies (Liu et al., 2018; Pahl-Wostl et al., 2021). The effective management of semi-natural grasslands requires multiple sectors (e.g., agriculture, conservation, spatial planning) to produce synergistic rather than antagonistic effects across levels and sectors as well as administrative levels (e.g., local vs. national).

A challenge particularly for small-scale extensive animal farmers in all regions relates to the specific design of the regulations associated with animal husbandry in general and subsidy payment in particular, which adds up to a high bureaucratic workload, tight farming regulations and regulatory misfits. For example, farmers keeping grazing animals are faced with rather expensive construction requirements regarding stables to address eutrophication and environmental pollution. While this is certainly necessary in view of large-scale non-extensive animal husbandry operation, the requirements are almost not fulfillable for small-scale extensive grazing animal holders in practice. In the Estonian case, for instance, farmers hire consultants to be able to meet the requirements of the complicated rule systems, who are expensive and hardly affordable for small-scale farmers (Interview EST1). Moreover, subsidies from various sources are a key tool for extensive grazing animal farmers to sustain semi-natural grassland conservation and restoration efforts. A key concern is that the regulations to obtain subsidies are not well aligned with small-scale animal husbandry practice. In the German study area, for instance, the reception of the conservation subsidies is coupled with specific grazing regulations, which do not necessarily match the daily reality of extensive animal holders well. An informant states in regard to these regulations that "*I can't hang the animals on a hook in the cupboard over winter.* (…) *If the* [anonymized authority] *tells me: You may from 1st of May to 30th of September go on the land. Then I always say quite heretically: yes and after that? I can't feed the animals for the remaining months with the hundred Euros you give me.*" (Interview GER-IGO2). In Estonia, a respondent furthermore explains that "*There are loads of different financial support plans. Those who have opportunities to apply several plans, risk the chance that the requirements of different support plans mismatch. Whenever and how well they try, something always crosses over.*" (Interview EST1). These statements illuminate some of the complications caused by the complex policy framework and the lack of fit to the specific context of small-scale farmers involved in semi-natural grassland conservation and restoration efforts.

A synergistic interplay of sectoral policies and planning tools is also needed at the wider landscape scale. Agri-Environmental Schemes, for instance, have high potential to play an important role for conservation and restoration at the landscape scale, because they promote biodiversity better than conventionally managed fields (Batáry et al., 2015; Zingg et al., 2019). Especially when no other semi-natural grasslands are present in the surroundings, sites with Agri-Environmental Schemes might act as species sources or stepping stones and therefore facilitate species richness, species interactions and ecosystem functions. For instance, arthropod species richness and biomass in grasslands decreases most strongly in sites surrounded by intensively managed agricultural crops (Reverter et al., 2021; Seibold et al., 2019). Moreover, directly adjacent arable fields with intensive management reduce insect-pollinated plant density in semi-natural grasslands (Clough et al., 2014). Extensification of agricultural fields with Agri-Environmental Schemes in the surroundings of semi-natural grasslands might therefore be a key component for successful conservation and restoration planning. However, these potential synergistic effects were hardly found to be considered in spatial conservation planning in our study regions.

The Estonian case highlights the successful interplay between different types of subsidies; in that case support for restoration (for details see (Republic of Estonia, 2023a) and management (for details see (Republic of Estonia, 2023b). While the restoration support is financed by the Estonian state and restoration projects through the EU, the management support is tied to the European CAP subsidies. These policies together contributed to an average increase of 2400 ha of semi-natural grassland through restoration per year across Estonia during the period 2014–2018, including ca. 200 ha of dry calcareous grasslands per year (Holm et al., 2019). The synergistic interplay between the different types of subsidies, in combination with favorable ecological conditions, thus led to a slow but steady increase of managed dry semi-natural grasslands over the last 15 years in the study region.

The fit of the European and national policies targeting semi-natural grassland conservation and restoration highly depends on their implementation in the regional context. The case of Estonia shows how subsidy programs can support targeted large-scale conservation efforts with the potential to reverse the trend of losing semi-natural grassland areas. The illustrations from all study regions, however, highlight that the interplay between the sectoral policies generally hardly creates synergistic, but rather antagonistic effects, and that the lack of fit to local social-ecological context creates severe challenges; particularly with respect to the inclusion of small-scale and spare-time ("hobby") animal farmers. A synergistic interplay of the different policies to support grassland conservation at the wider landscape scale has high potential for improvement in the study areas.

3.1.4. Changing climate conditions

Climate change poses a severe challenge to semi-natural grassland conservation and restoration efforts. The expected increase in the frequency and the magnitude of weather anomalies may alter grasslands' composition and diversity of plant species (Zavaleta et al., 2003). Moreover, longer and more extreme drought periods reduce biomass productivity (Grime et al., 2008) and floral resources with possibly detrimental effects on higher trophic levels such as pollinators (Fartmann et al., 2022; Phillips et al., 2018). The likelihood and strength of these effects may be region-specific (Ivits et al., 2014).

Changing climate conditions do not only directly affect the ecological communities in the grasslands, but also have consequences for the extensive farming practices. For instance, during droughts, and subsequent declines in biomass productivity, the animals need to be supplied with additional food and water. This further increases the investment of financial and time resources. Increased costs may also be caused by a decrease of animal health status with effects on meat or milk production, since drought periods reduce the pastures' fodder quality and jeopardize the welfare of the animals, which suffer from heat (Scocco et al., 2016). This affected, for instance, several herders in the Catalonian study area during the drought in 2022–2023. As a consequence, some regional administrations in Spain had to temporally relax policy requirements (e.g., livestock load), or farmers have been given extra aids to face the increase of production costs. Severe droughts have recently also occurred in the Estonian and German study regions with strong impacts on the extensive animal farmers. A German respondent noted in this regard in the context of the dry summer of 2022 "(…) *I have to look after the animals on Sundays too, control now with the drought, driving water quite extremely. Then there's the problem that the fodder is now becoming scarce, especially on calcareous grassland. It's just too dry.*" (Interview GER-IGO2). The anticipated increase in duration and frequency of droughts in many European regions will lead to an increase in cost for management and poses a severe future challenge for semi-natural grassland conservation and restoration efforts.

Experiences from our regions during recent decades show further impacts of climate change on semi-natural grassland management efforts. For instance, the Golden Jackals (*Canis aureus*) have expanded their range across Europe (Rutkowski et al., 2015) and the core habitat

of the predator now also coincides with our Estonian study region. While the large expansion of Golden Jackals seems to be a combination of multiple factors, the direct and indirect impacts of climate change in the form of reduced snow cover in Estonia (Viru and Jaagus, 2020) may favor their abundance (Spassov and Acosta-Pankov, 2019). The resultant socio-economic challenges of this predator are similar to the ones previously described for the presence of the wolf in Germany.

The challenges associated with direct site-level impacts of climate change on semi-natural grassland vegetation have received some recent attention in the literature (Geppert et al., 2021; Klinkovská et al., 2024; Mazalla et al., 2022). However, the wider impacts on the socio-economic dimension of restoration and conservation efforts have not been sufficiently acknowledged, but already pose an increasing challenge in practice. Insights from the cases clearly show that suitable adaptation measures will be needed in the very near future to avoid overgrazing and compensate for increased investments needed by farmers. Moreover, emergent range shifts resulting from climate change may also impact semi-natural grassland management and are likely to lead to further impacts on management in the future.

3.1.5. Changing rural societies

Rural depopulation and economic marginalization are increasingly becoming a general challenge in Europe (ESPON, 2017). Moreover, population aging has recently been recognized as an emergent problem for sustainable development (Kudo et al., 2015). These trends also have strong repercussions on the conservation and restoration of semi-natural grasslands in our study regions.

Our study area in Estonia is a good example of these demographic developments. When comparing the demographic structure in the rural study area in Estonia with the two largest towns (Tallinn and Tartu), our study area has proportionally more people in age groups 50 years and older, but proportionally less people in in age groups 30–50 years (Statistics Estonia, 2024). As mentioned by the interviewees, "*Young people tend to prefer other types of jobs. And farms where nobody takes over just stop animal husbandry*" (Interview EST1). There are also several examples of young city people moving to the Estonian countryside, but they often continue working remotely in non-farming-related jobs and do not take up traditional animal husbandry. An Estonian respondent put it in the following words: "*Young people go to study business administration or IT. No one wants to come here to maintain the animal husbandry - it is an exhausting and dirty work. And not paid well, and depends a lot on the weather*" (Interview EST1). In Germany, a respondent in the age 60+ similarly noted that "*I hardly know any younger people who want to do that. I don't know what will happen after me*" (Interview GER-IGO2). The reasons for the discontinuance of extensive grazing in the generational shift are manifold and knock-on effects diverse. A respondent in Spain explains in this regard that "*It's a mixture of everything. I think one thing leads to the other as well.* […] *Now it has become an unattractive job and there is little replacement in livestock, there is little replacement in agriculture, family businesses of any kind are disappearing.*" (Interview SP1).

While extensive animal farming has been practiced all across Europe for centuries, today's drop-out of older farmers not only leads to a decreasing workforce in semi-natural grassland management, but also to a declining number of knowledge holders related to traditional animal farming practices. This loss of persons, animals, knowledge and experience seriously jeopardizes efforts to restore and conserve biodiversity in semi-natural grasslands. Additional knock-on effects of decreasing extensive farming practices are the associated loss of physical and economic infrastructures as well as the necessary services, including sheep shearing, slaughter facilities and marketing opportunities for related products (e.g., wool, meat etc.). One respondent in Germany noted in this respect: "[…] *we have already had the problem in Lower Saxony that many structures have collapsed here. In other regions, it's even worse.*" (Interview GER-IGO-CS1). Re-building socio-economic infrastructure and knowledge related to traditional extensive animal farming in modern rural societies – once it has disappeared – is a daunting task.

3.2. Pathways to improve semi-natural grassland biodiversity management capacity

The five challenges occur all over Europe, yet are highly context specific in their impact and require measures adapted to their local to regional socio-ecological circumstances. The following three pathways represent our general recommendations to enhance management capacities to better address these challenges locally (see Fig. 2). These recommendations are, in large parts, derived from our empirical observations of some promising practices in the studied regions.

3.2.1. Semi-natural grasslands as social-ecological systems

Recognizing semi-natural grasslands as nested social-ecological systems offers an important avenue to include a thus far insufficient focus on the "human" dimension in conservation and restoration efforts (Bardgett et al., 2021; Herzon et al., 2021; Järv et al., 2021; Tedesco et al., 2023). Past and current site-level semi-natural grassland management practices (e.g., specific grazing regimes) are well known to be important determinants that explain successful biodiversity conservation and restoration outcomes (Török et al., 2021). However, as we show in the previous section, success in semi-natural grassland management is also tightly linked to the wider socio-economic circumstances affecting the capacity and motivation of animal holders to carry out suitable grazing regimes.

The challenge of profitability of extensive livestock farming in combination with changing rural societies in many parts of Europe provides a viable threat to grassland conservation and restoration efforts. A long-term focus on improving the wider socio-economic conditions for extensive farming systems, or rebuilding them, is therefore imperative to ensure successful long-term semi-natural grassland management. We wish to emphasize that several farmers conducting extensive farming in our study regions were not primarily driven by profit. Nonetheless, if these actors are not able to acquire enough revenue to cover their costs (and time investments), the likelihood that they will maintain these practices over time is low. Strengthening the focus on its cultural heritage, rooted in local values and rural traditions, may be an avenue to add value to regional products of extensive animal farming on semi-natural grasslands for local consumption and ecotourism purposes. In our Estonian study region, for instance, such cultural heritage framing in combination with the establishment of an umbrella organization, which serves as a business-to-business platform, is used for joint marketing. Such efforts can help to obtain adequate prices for the more expensive livestock products from semi-natural grassland.

Another important aspect requiring a social-ecological systems lens relates to navigating semi-natural grassland conservation and restoration efforts at the landscape scale. Spatially organizing the multiple demands is a complex task, because it has to go beyond the simple distribution of land for a distinct purpose (e.g., forestry, agriculture, settlements etc.) to reduce habitat fragmentation, but also should include mediating conflicts emerging from trade-off effects on semi-natural grassland conservation and restoration efforts. Such conflict, for instance, emerges where intensively managed arable fields are located directly next to nutrient poor semi-natural grasslands.

3.2.2. Recognizing grasslands as ecosystem service providers

Increased societal awareness and public knowledge of the multiple values of semi-natural grasslands represent another promising pathway to enhance the success of conservation and restoration activities (Calaciura and Spinelli, 2008). This involves increased efforts to reframe the value of semi-natural grasslands from agricultural "wastelands" – i.e., areas with limited productivity in the agricultural system – to not only acknowledge their biodiversity value (Gómez-Catasús et al., 2023; Traba and Pérez-Granados, 2022), but also their role in the context of climate change and its region-specific impacts.

Recent research shows that open semi-natural grasslands have a

carbon sequestration capacity equal to afforested grasslands (Prangel et al., 2023) and store more carbon than cropland (Bai and Cotrufo, 2022). Especially low grazing intensity (seasonal and rotational grazing) promotes soil carbon storage in grasslands, whereas heavy (continuous) grazing consistently reduces soil carbon stocks, especially in dry areas (Bagchi and Ritchie, 2010; Bai and Cotrufo, 2022; Zhou et al., 2019). Moreover, semi-natural grassland habitats enhance habitat connectivity and facilitate species dispersal. According to the spatial insurance hypothesis, these mechanisms increase stability and resilience of ecosystems (Gonzalez et al., 2020). The importance of semi-natural grasslands for ecosystem functioning is likely to increase with warming climates. Plant and animal species, that are associated with these habitats, are well adapted to nutrient-poor and dry conditions (Dengler et al., 2014). Thus, these grasslands harbor species and genetic information that might support evolutionary processes leading to adaptation of populations to warmer and dryer conditions in future European climates (Gradl et al., 2022).

Semi-natural grasslands can also contribute to the prevention of heat-induced wildfires, which are expected to increase in frequency and intensity especially in the southern parts of Europe with warming climates (Ruffault et al., 2020). The maintenance of grazed semi-natural grasslands, especially within areas with large forest cover, can help to reduce the risk of wildfire, because they have low fuel loads (Jones, 2022) and livestock contributes to avoid fuel accumulation (Bertomeu et al., 2022; Rouet-Leduc et al., 2021). Even in primarily herbaceous regions, the abandonment of grasslands and the disappearance of grazing, can lead to a considerable increase in wildfire probability, high flame length probability, and wildfire size (Salis et al., 2022). In fire prone areas, management of semi-natural grasslands can thus help to reduce wildfire risk (Toro-Mujica et al., 2015).

Hence, despite their marginal direct economic value for farmers (e.g., fodder), in the context of climate change semi-natural grasslands represent high value sites with regards to long-term and stable provisioning of ecosystem functions and services for resilient agricultural landscapes (Metz et al., 2020) and for preventing large wildfires, which can cause tremendous economic loss (Rouet-Leduc et al., 2021). Improving the awareness of semi-natural grasslands as ecosystem service providers and their consequent indirect monetary value more strongly in the public discourse can help to increase political will for sustaining the necessary traditional extensive grazing regimes and may contribute to activate more farmers as well as non-farmers to engage in semi-natural grassland conservation and restoration.

3.2.3. *Policy alignment and experimental learning*

Policy learning – i.e., the change of policies in response to new developments and needs (Bennett and Howlett, 1992; Moyson et al., 2017) – based on experimentation and adaptive policy alignment at multiple levels in the political system is a particularly important pathway. The description of the five challenges shows that embedding the current conservation and restoration strategy into a more encompassing and flexible policy framework to better embrace the local needs of different types of extensive farming systems is urgently needed.

Large-scale extensive farming remains key for Europe's conservation and restoration efforts, especially where large continuous grasslands exist (e.g., in our Estonian study region). The profitability challenge, however, shows that current policies need to make extensive farming financially more attractive to ensure continued management of large-scale operators. This objective could be achieved through further innovations with regards to agri-environment payments of the Common Agricultural Policy of the European Union (EU), by which subsidies for commodity production are used as payment to support environmentally benign farming practices (Fischer et al., 2012). This should be complemented by targeted national to local efforts to support extensive animal farming practices – as for instance evident in our Estonian study region. Small-scale farmers with lower numbers of grazing animals (e.g., dominant in our German study region), who engage in grassland management as a side activity or hobby, can complement the efforts and may play an increasingly important role in future grassland management in some European regions, especially where semi-natural grassland sites are small and landscape fragmentation is high. Our study shows that especially such smaller-scale farmers require low bureaucratic effort associated with extensive animal husbandry and semi-natural grassland management coupled with easy access to relevant local knowledge and technical support. Suitable ways to better meet the demands of different types of extensive farmers and the needs of semi-natural grassland conservation and restoration may be explored through experimentation locally.

One key element of policy learning relates to searching for ways to capitalize on cross-sectoral synergies to add monetary and non-monetary value to extensive grazing of semi-natural grasslands. In Spain, for instance, some policies have already been implemented at the regional level with the aim to promote extensive grazing as a wildfire prevention strategy over the last decade (e.g., Valencian Community and Andalusia). These policies focus on previously identified high wildfire risk areas and fix a minimum and a maximum livestock load that needs to be achieved during several years by herd owners. Experimenting with such policy design options (e.g., a wider fire prevention landscape planning) has strong potential of creating beneficial outcome for both, biodiversity conservation and wildfire prevention, and adds additional value to traditional forms of extensive grazing in modern landscapes. This value may be coupled with additional monetary incentives to attract herders to help prevent damage from wildfires at larger scales and provide space for policy innovation. One way to raise such complementary funds may be Payments for Ecosystem Services (PES), which is a mechanism to translate external, non-market values of the environment into real financial incentives for local actors to provide landscape-scale environmental services (Engel et al., 2008). Experimenting with such payment schemes, and how to operate them with minimal bureaucratic effort, seems to be a viable option in the context of semi-natural grassland management and have been successfully employed to finance other nature conservation efforts worldwide (e.g., in relation to forests) (Le et al., 2024).

Communities of practice (CoP) are an important pathway to promote innovation through strengthening regional self-organizing capacities. CoPs require nurturing of social relationships among people that develop around topics that matter to them (Lave and Wenger, 1991), such as extensive farming on semi-natural grasslands. The fact that they are organized around some particular area of knowledge and activity gives the group a sense of joint expertise, enterprise and identity (Wenger, 2000). CoPs can thus be understood as stable social networks that generate and manage knowledge. Because the results of local experimentation and learning processes are preserved in shared roles and practices in such networks, they create social capital that goes beyond individual knowledge and skills (Pahl-Wostl et al., 2007). Insights from our study regions show that CoPs exist in the context of semi-natural grassland conservation and restoration in different forms. As an example, in the German study region, a CoP is organized in the form of an NGO, which closely collaborates with the district administrative personnel on different conservation aspects pertaining to semi-natural grasslands. Especially the organization of regular meetings of people engaged in extensive animal husbandry is highly valued. One German farmer highlights in this regard that "*There you can exchange about fears, worries and needs and we create perhaps also a familiar togetherness.*" (Interview GER-IGO-CS1). Social capital is thus built that helps to address persistent and emergent challenges locally, such as ways to deal with the wolf, the impacts of climate change, the generational shift problem, or the (re-)establishment of regional socio-economic structures necessary for more profitable extensive animal farming.

These selected insights from our case regions provide some practical examples for experimenting with new strategies, by which actors try to find innovative ways of embedding traditional forms of extensive agriculture in modern rural societies and contemporary agricultural

systems. Moreover, we highlight the necessity for building local organizational capacities to facilitate this adaptive process. It remains important to note that developing adaptive strategies is a trial-and-error endeavor in the distinct regional social-ecological contexts. Some strategies might be successful in one region, but not in another. Effective policy learning requires an open attitude and the courage to try things out. Especially enabling and supporting the (self-)organization of regional CoP can be a viable strategy to move beyond blue-print approaches (cf. Ostrom, 2007) in semi-natural grassland conservation and restoration with the aim of increasing adaptive capacity and creating innovative solutions for dealing with the presented key challenges locally.

4. Conclusions

Semi-natural grasslands remain underappreciated in the sustainability discourse and international environmental policy (Bardgett et al., 2021), yet play a key role for biodiversity conservation globally (IPBES, 2019) and for building resilient agricultural landscapes in Europe (Lucie et al., 2023). We highlight five key challenges for the conservation and restoration of semi-natural grasslands in Europe. The challenges are *Profitability*, *Trade-off and lock-in effects*, *Policy fit & interplay*, *Climate change* and *Changing rural societies*. Moreover, we suggest three general pathways to organize the development of region-specific measures in practice. These pathways can help policy-makers to implement strategies for addressing these challenges:

A) Adopting a *holistic social-ecological systems perspective* is an important first step to ensure semi-natural grasslands can be sustained through stabilizing and rebuilding the necessary preconditions for extensive farming practices locally. This requires widening the angle of the somewhat narrow site-level technical-administrative ecological view in the conservation and restoration community. Improved monetary incentives, reduced administrative barriers and a stronger focus on non-monetary benefits are needed to sustain and strengthen the engagement of the diverse set of extensive farmers presently involved in semi-natural grassland management across Europe.

B) Working towards *a wider ecosystem service-based perspective of semi-natural grasslands at the landscape scale*. This involves shifting the perspective on grasslands from being agricultural "wastelands" to not only acknowledge their conservation/biodiversity value, but also their role as key cornerstones of resilient agricultural landscapes in the context of climate change and its region-specific impacts. This will be particularly important for increasing political and public will to better support semi-natural grassland conservation and restoration and may contribute to activate more farmers as well as non-farmers to engage in the future. Furthermore, successful conservation and restoration of semi-natural grasslands is not only linked to if and how extensive farming practices are conducted in a specific site (Poniatowski et al., 2018), but also to the embeddedness of a site in the wider landscape (e.g., ensure habitat connectivity) (Kormann et al., 2019; Lindborg et al., 2008).

C) *Experimental learning and policy alignment* across different levels in the political system is needed to co-create innovative solutions to adapt semi-natural grassland conservation and restoration efforts to regionally distinct socio-ecological contexts of modern landscapes. This pathway is tightly linked to finding better ways to embed traditional forms of extensive agriculture in today's rural societies and contemporary agricultural policies across Europe. Especially supporting local Communities of Practice offers a promising way to maintain local knowledge, facilitate the emergence of innovative farming practices and support local engagement. This can help to make extensive farming more attractive and feasible for younger generations and other newcomers that might be willing and eager to help preserve the cultural landscape while, at the same time, need to find ways to sustain adequate incomes through modern forms of agriculture.

The insights from this study are highly relevant for implementing current and future biodiversity strategies of the EU and national levels. The identified challenges and the suggested pathways gain increased salience in the context of the recently adopted legislation on nature restoration in the EU (EU Regulation 2024/1991 and amending EU Regulation EU 2022/869). Implementation will require tremendous EU-wide future efforts at various administrative levels also with regards to semi-natural grasslands. If the local extensive farming systems necessary to manage semi-natural grasslands areas are not better supported, however, conservation and restoration efforts following the envisaged EU targets are unlikely to succeed. This study provides a simple diagnostic framework for action to improve future planning and implementation in practice.

CRediT authorship contribution statement

Philipp Gorris: Writing – review & editing, Writing – original draft, Visualization, Validation, Project administration, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization. **Örjan Bodin:** Writing – review & editing, Validation, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization. **David Giralt:** Writing – review & editing, Project administration, Investigation, Funding acquisition, Data curation. **Annika L. Hass:** Writing – review & editing, Project administration, Investigation, Funding acquisition, Data curation. **Triin Reitalu:** Writing – review & editing, Validation, Project administration, Investigation, Funding acquisition, Data curation. **Xabier Cabodevilla:** Writing – review & editing. **Ira Hannappel:** Writing – review & editing, Visualization. **Aveliina Helm:** Writing – review & editing, Project administration, Funding acquisition. **Elisabeth Prangel:** Writing – review & editing. **Catrin Westphal:** Writing – review & editing, Project administration, Funding acquisition.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used "Playground" AI in order to generate the two pictures included in Fig. 2. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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Data availability

The authors do not have permission to share data.

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