BURLEIGH DODDS SERIES IN AGRICULTURAL SCIENCE

# Advances in temperate grassland science and management

Edited by Dr Agnes van den Pol-van Dasselaar

E-CHAPTER FROM THIS BOOK

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SCIENCE PUBLISHING

# Grasslands in Europe: current status, emerging challenges, and pathways to sustainable futures

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## 1 Introduction

Grasslands are a cornerstone of European agriculture, supporting both food security and a wide range of ecosystem services. Covering approximately one-third of the utilized agricultural area in Europe, grasslands contribute to a range of ecosystem services. Ruminants such as cattle, sheep, and goats can transform the feed source grass that is inedible to humans into high-quality protein-rich foods, in the form of meat and milk. Grasslands also support biodiversity conservation, carbon sequestration, nutrient cycling, water regulation, and cultural values, while sustaining rural economies and communities. Historically shaped by traditional farming practices such as grazing and haymaking, European grasslands have evolved into vital habitats and production landscapes.

Yet European grasslands are at a crossroads. Climate change, land-use competition, socio-economic pressures, changing dietary preferences, and evolving policy frameworks are reshaping how grasslands are managed and valued. At the same time, technological advances and collaborative innovations

http://dx.doi.org/10.19103/AS.2025.0154.26


Chapter taken from: van den Pol-van Dasselaar, A. (ed.), *Advances in temperate grassland science and management*, pp. 507–532, Burleigh Dodds Science Publishing, Cambridge, UK, 2025, (ISBN: 978 1 80146 902 9; www.bdspublishing.com)

offer new opportunities to enhance the multifunctionality of grassland-based systems.

This chapter provides a coherent, integrated overview of grasslands in Europe, addressing (1) their current status and use, (2) the ecosystem services they provide, (3) the major drivers and trends affecting them, and (4) promising innovations and research directions. These are illustrated by a case study from the project Grazing4AgroEcology that shows how innovative farmers, researchers, and other stakeholders are now jointly exploring new approaches. Throughout the chapter, we advance the central argument that grassland systems can, if appropriately managed and supported, simultaneously deliver nutritious food and multiple ecosystem services, thereby contributing to resilient agricultural futures in Europe.

# 2 Current status of grasslands in Europe

## *2.1 Grassland typology*

European grassland-based livestock systems range from extensive, low-input systems relying on semi-natural pastures to highly intensive pastures managed for maximum productivity. Regarding the typology of grasslands, definitions have been proposed by Allen et al. (2011) and Peeters et al. (2014). In recent years, several EU joint research projects (e.g. MULTISWARD, Super-G) have attempted to more precisely and quantitatively capture the diversity of European grasslands in terms of environmental conditions, management, and comprehensive ecosystem services. The most complex typology to date has recently been presented as part of the Super-G project and takes into account a stronger differentiation of the intensity of grassland use (Tonn, 2024). This classification can serve as a reference, particularly for the precise spatial characterization of ecosystem services and for informing agricultural policy related to their classification and promotion.

In this chapter, we propose a simplified typology with four grassland types, characterized by vegetation, sward persistence, and grassland management (Isselstein and Komainda, 2021). They are built on widely used typologies and help frame ecosystem functions and management needs.

- Cultivated permanent grasslands: regularly and intensively managed grasslands aiming at a high yield and forage quality, i.e. renovated, fertilized, weeds controlled, sown species more or less dominating, not part of a crop rotation.
- Permanent grasslands: regularly and more or less intensively managed, moderately yielding, contain perennial or self-seeding forage species, persist indefinitely, sown species not or less dominant.

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- Temporary grasslands/leys: sown grasslands composed of forage species, integrated into arable crop rotations, sown species dominate.
- Semi-natural grasslands: extensively managed, low yield potential, permanent grasslands/habitats, vegetation dominated by indigenous and naturally occurring species.

This typology is used throughout the chapter to interpret differences in ecosystem service provision.

### *2.2 Grassland area and distribution*

Grasslands are an essential part of agriculture in every European country. Permanent grasslands cover almost one-third of the utilized agricultural area in the European Union (Eurostat, 2025a) (Table 1). Permanent grassland is defined by Eurostat as "land used permanently (for several consecutive years, normally 5 years or more) to grow herbaceous fodder, forage or energy purpose crops, through cultivation (sown) or naturally (self-seeded), and which is not included in the crop rotation on the holding. The grassland can be used for grazing, mown for silage and hay, or used for renewable energy production. Grassland must have fodder interest, i.e. they include vegetal species of fodder interest." Temporary grasslands (leys) are typically counted under arable land because they alternate with crops in rotations. In total, permanent and temporary grasslands can be considered the main land use in Europe.

Fig. 1 shows the distribution of permanent grasslands in the different Member States of the European Union. In some countries, grasslands are the main land use (e.g. Ireland), while they are less prominent in other countries (e.g. Finland or Bulgaria). National averages often mask substantial within-country regional differences where grasslands are critical to local economies and ecological networks.

Historically, the area of grasslands in Europe has fluctuated (Küster, 1995; Poschlod, 2016). Forest clearing for agriculture over millennia expanded grasslands. Winkler et al. (2021) showed that grasslands are not only historically shaped but also currently undergoing regionally distinct transitions. In the last

**Table 1** Grassland areas in the EU-27 (million ha)

| | 2012 | 2016 | 2020 | 2023 |
|---|---|---|---|---|
| Permanent grassland | 48 | 49 | 51 | 51 |
| Arable land (including temporary grasslands) | 99 | 100 | 98 | 97 |
| Permanent crops | 12 | 12 | 12 | 12 |
| Utilized agricultural area | 161 | 161 | 162 | 161 |

*Source*: Eurostat (2025a).

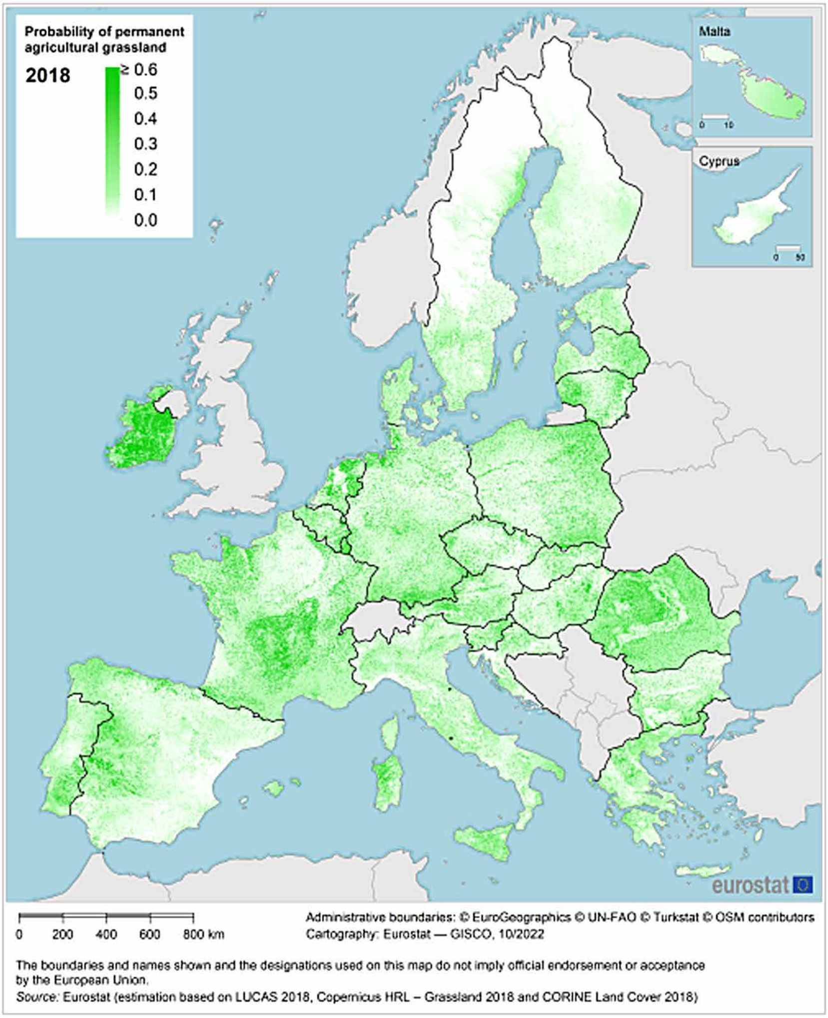


**Figure 1** Probability of permanent agricultural grassland in Europe (https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Permanent_agricultural_grassland_in_Europe; Eurostat, 2025b).

decades, the area of permanent grassland declined more sharply than the total utilized agricultural area (Huyghe et al., 2014; FAO, 2025). The main reasons for the loss of permanent grasslands were the conversion of grasslands into arable crops (32% of the lost area), urban expansion (30%), and land abandonment in rural areas (17%) (Erhard et al., 2016). Winkler et al. (2021) suggested that the regional mosaic underscores why policy and management must be tailored to local biophysical and socio-economic conditions.

### *2.3 Grazing in Europe*

The primary and most significant function of European grasslands is the production of animal feed, i.e. grazed or conserved forage, particularly for ruminant livestock such as cattle, sheep, and goats. Ruminants possess a unique digestive system that enables them to convert fibrous plant material, which is indigestible to humans, into valuable food products for humans such as milk and meat. This process plays a crucial role in the agricultural economy and food supply chain, making grassland management a vital aspect of sustainable farming.

Traditionally, grazing was the main management practice on grasslands in Europe. Grazing by dairy cows, beef cattle, and small ruminants remains a defining feature of many European grassland systems. However, the proportion of dairy cows that graze has declined in several countries over the past two decades, with notable regional variation. Estimates derived from grazing experts throughout Europe showed a decrease in the period 2001–2019 in the percentage of dairy cows grazing (Van den Pol-van Dasselaar et al., 2020). More recent data from 2022 to 2024 show that this trend has continued, with a few exceptions (Table 2).

Some of the reasons for the decline in grazing across Europe include, in no particular order, the variability in herbage production and quality, lack of available labour, year-round calving patterns, use of high genetic merit cows, which require a steady supply of high-quality feed, increasing number of cows per farm and land fragmentation (Hennessy et al., 2020). There is a requirement for a robust type of cow, which can deal with the grazing conditions presented including topography, distance from the milking parlour, and variability in feed (grass) supply and quantity (Friggens et al., 2017; Delaby et al., 2021). Many breeding programmes across Europe are not designed to produce cows for pasture-based systems, rather cows fed indoors on concentrate-based diets with little variability in feed quality and with little emphasis on dairy cow fertility. Seasonal pasture-based systems require a level of seasonal calving to optimize the use of grazed grass in the diet and therefore demand a focus on fertility (Delaby et al., 2021). For example, in Ireland, the Economic Breeding Index focusses on fertility, maintenance/robustness, and milk solids production (Veerkamp et al., 2002; Berry et al., 2022).

The trends in grazing in Europe over the past decades are further illustrated in Fig. 2. This figure provides data on grazing from three countries, each with its own trends and challenges. While the percentage of grazing in Ireland is still very high, the percentage of grazing in Denmark has dramatically declined in the last 25 years. The percentage in the Netherlands lies in between.

**Table 2** Grazing in Europe (% dairy cows) in six distinctive regions of Europe

| Region and country | 2010 | 2014 | 2016 | 2019 | 2022 | 2024 |
|---|---|---|---|---|---|---|
| North | | | | | | |
| Norway | | | 90 | 80 | 75–95 | 95–100 |
| Sweden | 100 | 100 | 100 | 100 | 100 | <100 |
| Finland | | | 70 | 80 | 60-80 | 60–70 |
| West | | | | | | |
| Ireland | 99 | 98 | 95–100 | 95–100 | 90–100 | 95–100 |
| UK | | 92 | 80–90 | 70–80 | 70–90 | 65–95 |
| Central; grazing >50% | | | | | | |
| The Netherlands[a] | 74 | 69 | 65 | 73 | 75 | 69 |
| Belgium[b] | 85–95 | 75–80 | 60–85 | 30–95 | 40–90 | 50–90 |
| Luxembourg | 75–85 | 73 | 75 | | 30–50 | 20–50 |
| France | 90–95 | 90 | 75–95 | 90 | 50–90 | 40–90 |
| Switzerland | 85–100 | 75–90 | 80–97 | 70–90 | 88–96 | 70–90 |
| Central; grazing <50% | | | | | | |
| Denmark | 35–45 | 25–30 | 25 | 20–25 | 30 | 25–30 |
| Germany | 42 | | 10–50 | 15–40 | 20–50 | 15–50 |
| Austria | 25 | | 40 | 44 | 45 | |
| East | | | | | | |
| Poland | | | 20 | 30 | 30 | 25 |
| Lithuania | | 50–70 | | | | 20 |
| Czech Republic | 20 | | 3 | | 4 | 2–5 |
| Slovenia | 25 | | 20 | 20–40 | 20 | 20 |
| Hungary | | | 2–3 | 3–5 | 5–10 | 5 |
| South | | | | | | |
| Portugal | 50 | | | 60 | | |
| Spain | 20 | | 10–30 | 20–30 | 10–50 | 10–60 |
| Greece | 15 | | 10 | 10 | 5 | 5 |
| Italy | | | 10–20 | | 2–70 | 35 |

[a]Statistical data in 2010–2024 (CBS, 2025).
[b]Large regional differences between Flanders (low) and Wallonia (high).
*Source*: Period 2010–2019: Van den Pol-van Dasselaar et al., 2020; period 2022–2024: expert input from the Working Group "Grazing" of the European Grassland Federation.

In Ireland, grazing remains consistently high. The country's mild climate and abundant rainfall create ideal conditions for grass growth, making pasture-based dairy and beef production highly cost-effective. Additionally, much of the land area in Ireland is not suited to the production of other feeds such as maize and barley due to topography, soil type, and rainfall. Compared to indoor feeding systems, grazing significantly reduces feed costs, as grass is the

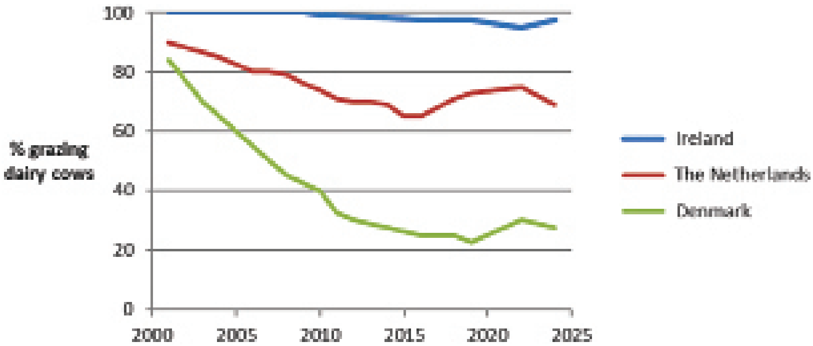


**Figure 2** Grazing (% dairy cows) in Ireland (expert opinion), the Netherlands (statistical data), and Denmark (expert opinion). Expert opinions originate from the EGF Working Group "Grazing" and are partly reported by Van den Pol-van Dasselaar et al. (2019).

cheapest source of nutrition for livestock (Finneran et al., 2010). In addition, grass-fed milk and dairy products have been shown to be of high quality for human nutrition (e.g. O'Callaghan et al., 2016; Alothman et al., 2019; Timlin et al., 2023). Grassland-based systems are heavily promoted by science and advisory services, and grass contributes over 95% of a cow's annual diet as fed in Ireland (O'Brien et al., 2018). Additionally, Ireland's dairy sector relies heavily on exports, and grass-fed dairy products are marketed as high-quality and sustainable, further reinforcing the economic motivation to maintain high levels of grazing.

In Denmark, grazing has steadily declined over the past decades as dairy farming has become increasingly intensified. Dairy farms have shifted towards larger herds and higher milk production, prioritizing efficiency and productivity. As a result, many farmers have moved towards indoor feeding systems that allow for better control over nutrition and milk yields. This trend has led to a significant reduction in grazing, as pasture-based systems are often seen as less compatible with the high-output dairy model that dominates Danish agriculture today.

In the Netherlands, dairy cows usually graze only for part of the day. Grazed grass is supplemented indoors with conserved forages and concentrates. Intensification has led to a decrease in the percentage of grazing dairy cows since 2000. From 2005 onwards, societal concerns regarding the decline of grazing practices grew significantly (Runhaar et al., 2020). In response to these concerns, a "Grazing Covenant" was established in 2012, bringing together more than 80 organizations from across the entire dairy supply chain. To support the goal of halting the decline in grazing, several initiatives were introduced, such as financial incentives (e.g. grazing premiums) and grazing advice for farmers (grazing coaches). This led to a reversal in the trend between 2015 and 2022. Recent data, however, show that the percentage grazing is once again decreasing. This can be associated with a shift in the attention of dairy companies to broader sustainability goals (e.g. reducing carbon footprints, enhancing biodiversity), thereby putting less emphasis on grazing. These trajectories show how markets, advisory systems, infrastructure, and policy interact to shape the extent of grazing.

Country-specific insight in the barriers to grazing was obtained in the Horizon Europe project Grazing4AgroEcology (Table 3). Table 3 is based on results of an online survey among young farmers in eight European countries (n = 1410) (Van den Pol-van Dasselaar et al., 2024).

Next to the identification of barriers, research has also identified many options to improve grassland production, quality and utilization. Incorporating legumes can result in increased herbage quality, dry matter intake and milk production (e.g. Egan et al., 2018; McClearn et al., 2019). Improving grazing management (O'Donovan and Delaby, 2016) and developing grazing management decision support tools/systems that translate data on pasture growth and animal demand into actionable decisions can help provide

**Table 3** Perceived barriers to grazing in France (FR), Germany (DE), Ireland (IE), Italy (IT, Sardinia = SA, South Tyrol = ST), the Netherlands (NL), Portugal (PT), Romania (RO), and Sweden (SE) as seen by young farmers (number of valid responses and % of respondents that chose a particular barrier in their top five barriers; only barriers with at least 40% are given for each country/region)

| | FR | DE | IE | ITSA | ITST | NL | PT | RO | SE |
|---|---|---|---|---|---|---|---|---|---|
| Number of valid responses | 458 | 116 | 58 | 33 | 59 | 456 | 43 | 111 | 76 |
| Barriers | | | | | | | | | |
| Climate (no grass in dry periods, heat stress) | 71 | 48 | 53 | 58 | | 52 | 65 | 47 | |
| Land fragmentation (not enough grazing land surrounding the farm) | 62 | | 70 | | 41 | 42 | | 42 | 50 |
| Lack of knowledge/education | 41 | | 77 | 58 | | | 40 | 59 | |
| Variability in grass quantity and quality | 56 | | 62 | | | 58 | | | 47 |
| Predators like wolves | | 64 | | | 79 | | | | 42 |
| Consumer demands for low prices | | 61 | | | | | 40 | | 67 |
| Time/available labour | | 52 | | | | 47 | 43 | | |
| Not enough grass available/low grass production when grazing | 41 | | | | | | | 45 | |
| Money, i.e. costs too high and/or benefit too low | | | | 42 | | | 43 | | |
| Unfavourable topography (e.g. the pastures are too steep) | | | | | 50 | | | | |

Source: Van den Pol-van Dasselaar et al. (2024).

confidence in decision-making (e.g. PastureBase Ireland, Hanrahan et al., 2017; MoSt Grass Growth model, Ruelle et al., 2018). Optimizing grazing systems means adjusting how livestock graze (timing, intensity, spatial patterns) to maximize benefits like food production and soil health, while minimizing harm to the surrounding ecosystem (e.g. avoiding overgrazing and soil erosion, and enhancing biodiversity).

## 3 Ecosystem services and multifunctionality

As mentioned in the previous section, the production of animal feed for ruminants leading to production of human food is the primary and most significant function of European grasslands. In many areas of Europe, this can occur without competing for land for crop production (Van Kernebeek et al., 2016) as grassland tends to occupy much of the land area unsuitable for crop production (access, topography, soil type, etc.). Grassland-based ruminant production systems can thus contribute to net human-edible protein when concentrates are minimized and diets are aligned with pasture supply (e.g. Mottet et al., 2018; Leroy et al., 2022). The net supply of edible protein by livestock can be considered using a number of metrics including feed conversion ratio (FCR; Wilkinson, 2011), total protein efficiency (Laisse et al., 2018), net protein efficiency (Laisse et al., 2018), edible protein conversion ratio (EPCR; Wilkinson, 2011; Laisse et al., 2019; Mosnier et al., 2021), and land-use ratio (LUR; van Zanten et al., 2016). Laisse et al. (2018) showed that the net protein efficiency of grassland-based dairy cattle production receiving low concentrate input is up to 2.57 in France, while Hennessy et al. (2021) reported a net protein efficiency of 4 for Irish grassland-based dairy cattle production systems (Fig. 3). This indicates that grassland- based ruminant production systems perform well in terms of converting feed protein to food protein and it highlights that grasslands (utilizing land unsuited to cropping) and arable lands are complementary in the production of human food.

Next to food production, grasslands provide many more ecosystem services, i.e. benefits to humans from nature (for recent reviews, see Bengtsson et al., 2019; Schils et al., 2022). Production services that play an essential role in supporting rural economies are closely related to grassland-based livestock farming, i.e. the products are milk, meat, and fibre (Isselstein and Kayser, 2014; Ryschawy et al., 2017). Other important services include the maintenance and enhancement of biodiversity (e.g. Habel et al., 2013; Isselstein, 2019), the purification and provision of clear ground and surface waters (Orr et al., 2016), the safeguarding of soil quality and reduction of soil erosion risks (Milazzo et al., 2023), climate regulation, including C sequestration (O'Mara, 2012; Bai and Cotrufo, 2022) and the provision of cultural services, i.e. recreation and landscape aesthetics (Pellaton et al., 2022; Jitea et al., 2024).

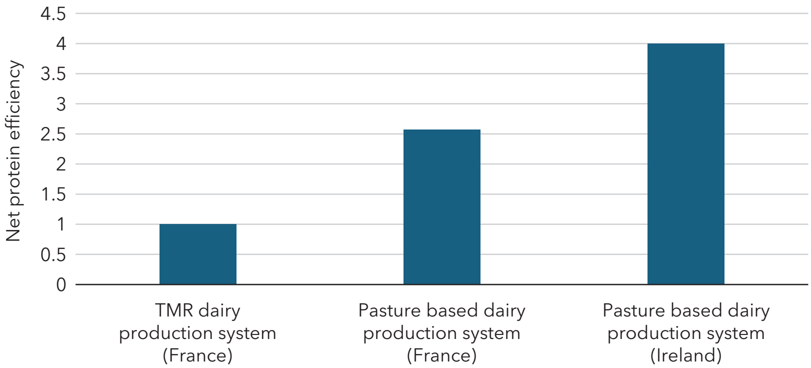


**Figure 3** Net protein efficiency of dairy production systems (kg human edible protein produced/kg human edible protein consumed by livestock) in France (indoor feeding TMR and grassland-based; Laisse et al., 2018) and Ireland (grassland based; Hennessy et al., 2021) Source: Hennessy et al. (2024).

Bardgett et al. (2021) showed that the provision of these services and the ecological functioning of grasslands are at risk in situations of grassland degradation. Also, when grasslands are converted into arable or other crop systems, provisioning of ecosystem services is under threat (e.g. Schils et al., 2022). Schils et al. highlighted the importance of permanent grasslands in supporting different ecosystem services and concluded that land use change and intensification decreases the multifunctionality of permanent grasslands. Table 4 summarizes typical patterns of the ecosystem service provision of grasslands across the four grassland types introduced earlier.

In addition to the grassland type, the site and management conditions of grasslands affect the ecosystem services that these grasslands deliver. This is illustrated in Fig. 5. This figure provides a simplified, generalized representation of the conditions under which maximum performance of various ecosystem services can be assumed. On the vertical axis of the matrix, the characteristics

**Table 4** Importance of ecosystem services provided from grasslands depending on the grassland type

| Ecosystem service | Cultivated grasslands | Permanent grasslands | Temporary grasslands | Semi-natural grasslands |
|---|---|---|---|---|
| Herbage production | +++ | ++ | +++ | + |
| Soil-C/C-sequestration | ++ | +++ | + | + |
| Nitrogen emission | ++ | ++ | ++ | + |
| Water provision | ++ | +++ | ++ | ++ |
| Biodiversity/genetic resources | + | ++ | - | +++ |

For explanation of grassland types, see 2.1; importance/priority: "+++" highest, "++" moderate to high, "+" low, "–" no.
Source: Isselstein and Komainda (2021).

or domains dependent on location and management are represented. On the horizontal axis, the various ecosystem services are presented. As an example, the highest production performance in terms of feed and food is achieved on fertile soils with adapted fertilization and frequent defoliation, making moderately high yields with very good feed quality possible.

The assessment in Fig. 4 can only be a rough representation of the complex relationships between location and management on the one hand, and ecosystem services on the other, and deviations from these generalized statements are possible. For example, with regard to climate impact of grassland farming, it is generally assumed that disturbance of the sward and/or the soil restricts carbon sequestration in the soil, which is therefore negatively assessed. However, a recent study shows that grassland improvement, which involved soil disturbance and reseeding, increased the productivity of the sward to such an extent that more carbon is captured and sequestered in the longer term (Feigenwinter et al., 2023). Recognizing such context dependencies is essential when designing policies and farm strategies that aim to increase multifunctionality rather than maximize a single service.

| Ecosystem service | **Food**: produce feed and food | **Nature**: protect and promote biodiversity | **Climate**: reduce greenhouse gas emissions, sequester carbon | **Water**: provide sufficient and clean water | **Culture**: preserve typical cultural landscapes |
|---|---|---|---|---|---|
| Domain/ Characteristic | | | | | |
| site/soil | fertile, well supplied with basic nutrients | rather low fertility, low in basic nutrients | no tillage and sward disturbance | rather low fertility, high water permeability | small paddocks, diverse landscape structure |
| soil water availability | moderate, no surplus, no drought | either dry or wet sites | wet on organic soils | no clear effect | diverse, from low to high |
| herbage quantity | Moderate | rather low | rather high | rather low for high water quantity, rather high for high water quality | diverse, from low to high |
| herbage quality | High | often low, mature herbage | high to reduce methane emission by ruminants, low crude protein content to reduce $N_2O$ emissions | low to moderate | diverse, from low to high |
| Fertilization | moderate to high | none to low | none to low | low to moderate | rather low |
| Defoliation | Frequent | infrequent | depending on methane or $N_2O$ emission, either infrequent or frequent | rather frequent | diverse, grazing, mowing, frequent, infrequent |

**Figure 4** Simplified representation of the site and management conditions (domain/characteristic) under which high or maximum performance is achieved for various ecosystem services that relate to food, nature, climate, water, and culture. Source: Isselstein (2021).

## 4 Drivers and trends of change

There are a number of major regional and global trends and challenges that may affect grasslands and grassland-based livestock production systems in Europe, shaping their productivity, sustainability, and role in society. These trends will not only lead to changes in the extent of grasslands but will also lead to changes in the way these grasslands are managed. This chapter discusses major drivers and trends of change and the implications they may have on grasslands in Europe.

### *4.1 Demographic trends*

- *Changes in population size.* The United Nations (2024) predicts that the world's population will continue to grow, with projections indicating an increase from approximately 8 billion people today to a peak of more than 10 billion around 2084. The global population increase will heighten pressure on resources, food systems, and environmental sustainability. The growth is predicted to be unevenly distributed across regions. Global population growth is driven primarily by countries in Africa and parts of Asia; Europe already had its peak in 1992. Population increase is coupled with an increase in global demand for food and animal protein in diets (Alexandratos and Bruinsma, 2012). On a per capita basis, global meat consumption is expected to grow by 2% by 2032 compared to the base period of 2020–2022, driven by income and population growth (OECD-FAO, 2023). To meet the food demand of this growing population, increased food production is required from approximately the same land area and in some regions such as Europe, from a declining land area because of competition with other land uses such as bioenergy production and urbanization (O'Mara, 2012). This will require increases in efficiency of production from grassland, as well as other agriculture. Europe faces relatively stable or declining populations with ageing demographics but participates in global markets where demand for animal-source foods continues to evolve. These dynamics place a premium on efficient, multifunctional land use, an area where grasslands, including those in Europe, can excel.

### *4.2 Resource use and land-use change*

- *Intensification.* In the last decades, roughly since the start of the CAP (Common Agricultural Policy of the European Union) in the early 1960s, grassland use in Europe has intensified: increased artificial fertilizer use, higher stocking rates, higher cutting frequency, more drainage and

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irrigation, more re-sowing and over-sowing, more weed control with herbicides (Peeters, 2009). As a result of intensification, the number of farms has decreased, while the average livestock numbers per farm and the land area per farm increased. The intensification of agriculture in Europe also led to the loss of grasslands on farms that were originally fully grass-based. To accommodate the increased energetic and nutritional needs of the animals, the feed ration has been supplemented with maize and concentrates. This led to conversion of grasslands into maize fields and arable lands to provide this supplementation. Ploughing grasslands for crops leads to severe biodiversity loss, soil carbon release, and hydrological changes that disrupt ecosystem functions. Grassland intensification boosts short-term productivity but often degrades soils, reduces biodiversity, and disrupts natural nutrient cycles. Over time, these systems can become less resilient to climate extremes and ecological stresses, threatening long-term sustainability.

- *Land abandonment*. This trend, that is in contrast with intensification, also occurred in Europe in the last decades (Peeters, 2009). In Europe, land abandonment was most common in marginal areas, which tend to be dominated by grassland, where farming was less economically viable, e.g. in mountainous or remote areas. Abandonment often triggers landscape changes, with grasslands gradually transitioning to shrubland or forest through natural succession. While this process can enhance carbon storage and woodland biodiversity, it reduces open-habitat species, reduces overall biodiversity, reduces agricultural productivity, and reduces the cultural value of traditional landscapes. These changes can disrupt rural communities, drive depopulation, and reshape local economies.

### 4.3 Societal expectations and market signals

- *Societal concerns*. Societal concerns regarding livestock systems have intensified in recent years, particularly with regard to greenhouse gas emissions, animal welfare, and the high land and water demands of these systems (Moran and Blair, 2021). Nutrient runoff and leaching, which degrade water and soil quality, and biodiversity loss linked to intensified production (Resare Sahlin et al., 2024) are also key issues. Growing public awareness of biodiversity loss, climate change, and animal welfare is reshaping expectations for grassland management. There is increasing pressure to adopt practices that enhance ecosystem services, improve animal welfare, and reduce environmental impacts. While this can support more sustainable and diversified management, it also challenges traditional practices and may require significant adaptation by farmers.

- *Dietary shifts towards plant-based alternatives*. The societal concerns and growing awareness of potential environmental problems related to livestock production in general are leading to dietary shifts. European consumers are increasingly replacing animal-based products with plant-based options (e.g. Mustapa et al., 2025). The rising demand for plant-based foods is reducing the reliance on livestock production in some regions, directly affecting grassland use. This trend can lead to lower grazing intensity and, in some areas, land abandonment or conversion to other uses. However, it may also create opportunities for grasslands to be managed for carbon storage, biodiversity, or other ecosystem services instead of meat or dairy production.
- *Socio-economic challenges*. Socio-economic challenges in agriculture are becoming increasingly prominent, with volatile prices creating financial uncertainty for farmers. A significant challenge is also the lack of collaboration between different actors in the food chain, which hinders the development of efficient and sustainable systems. Increasing price volatility and financial uncertainty make it difficult for farmers to invest in the long-term management of grasslands, often leading to under-management, intensification, or even abandonment. The lack of collaboration across the food chain further limits opportunities to develop value-added, sustainable grassland systems, such as premium pasture-fed products or ecosystem service markets. As a result, grasslands risk degradation or conversion, while their potential to support biodiversity, carbon storage, and resilient rural economies remains underutilized.
- *Policy instability*. In terms of policy, volatile politics can create an unstable regulatory environment, making it difficult for farmers to plan and invest in the long term. Shifting political priorities and policy changes can lead to uncertainty, impacting everything from subsidies to environmental regulations, and creating challenges for the agricultural sector in adapting to new demands and expectations. An example are the on-going, frequent changes to nitrogen and nitrates regulations in countries such as Ireland and the Netherlands. Shifting regulations make it difficult for farmers to adopt sustainable practices in grassland management or commit to infrastructure improvements. This instability can lead to reactive, short-term decision-making, increasing the risk of overuse, under-management, or even conversion of grasslands, and reducing their potential to deliver ecosystem services and long-term productivity.

### *4.4 Systemic trends*

- *Path dependency* (a phenomenon whereby history matters; what has occurred in the past persists because of resistance to change) is a trend that is often seen in agricultural production systems. It is an economic and social concept that suggests that the decisions and outcomes in a system or process are heavily influenced by the past or the initial conditions, even when those past circumstances are no longer relevant. Once a particular course of action is chosen, it can be difficult or costly to change direction, leading to a "locked-in" trajectory (Goldstein et al., 2023). Farmers often feel that they are locked in to their current system. For farmers in indoor systems, examples of lock-ins include investment in housing and feeding equipment, loss of grazing management skills/knowledge, and poor grazing infrastructure. For grass-based farmers, examples of lock-ins may include inflexible regulatory frameworks, consumer preferences for low-cost food, constrained access to financial resources when investments in sustainability are requested, and limited labour availability. These "lock-ins" can prevent the adoption of more sustainable or diversified practices in grassland management. They slow innovation and adaptation, leaving grasslands vulnerable to degradation, reduced biodiversity, and missed opportunities for enhancing ecosystem services and resilience.

- *Climate change*. Climate change is a threat to grasslands (e.g. Gibson and Newman, 2019). As a largely uncontrollable phenomenon, it is altering precipitation patterns, temperature regimes, and the frequency of extreme weather events. These shifts affect productivity, species composition, and seasonal growth patterns, reducing the reliability and quality of forage. Increased droughts, flooding, and volatile weather also disrupt grazing management and can accelerate soil degradation or erosion, ultimately threatening the resilience, biodiversity, and long-term sustainability of grassland systems.

## 4.5 Trends in agricultural systems

- *Organic agriculture*. The European Commission has set ambitious targets for organic farming in Europe. The European Green Deal's Farm to Fork strategy sets the target that at least 25% of the European Union's agricultural area should be dedicated to organic farming by 2030. The share of the European Union's agricultural land under organic farming increased from 5.9% in 2012 to 10.5% in 2022 as a result of an increasing demand for organic products and policy support (EEA, 2024). Organic farming is generally lower input, and grasslands play an important role in supplying feed for livestock.
- *Regenerative agriculture*. Another trend, increasing in popularity, is regenerative agriculture. There is no agreed definition of regenerative agriculture (for example, see reviews of Newton et al., 2020 and Schreefel et al., 2020), but it is receiving much attention from producers, retailers,

researchers, and consumers, as well as politicians and the mainstream media (Newton et al., 2020). Regenerative agriculture has been proposed as an alternative means of producing food that may have lower, or even net positive, environmental and/or social impacts (Rhodes, 2017). In many cases grassland-based farming that includes grazing systems has many of the attributes associated with the various interpretations of regenerative agriculture like integration of livestock, reducing or eliminating tillage, increasing biodiversity, and sequestering carbon (Newton et al., 2020). An increase in regenerative agriculture could lead to an increase in grassland area.

### *4.6 Implications for grasslands*

Grasslands are shaped by a complex interplay of environmental, socio-economic, policy, and societal drivers, each influencing their structure, function, and management. Intensification, conversion, and abandonment directly alter biodiversity, productivity, and carbon storage, while socio-economic pressures, policy instability, and path dependency constrain the ability of farmers to adopt sustainable practices in grassland management. Societal expectations, shifts toward plant-based diets, and climate change further reshape grazing patterns, management intensity, and landscape composition. Collectively, these trends create both risks, such as land degradation and soil erosion, species loss, and reduced resilience, and opportunities, including enhanced ecosystem services, and more diversified and sustainable grassland management. Understanding these interlinked drivers is essential for developing strategies that maintain the ecological, economic, and cultural value of grasslands in a rapidly changing world.

## 5 Case study: Grazing4AgroEcology

This case study from the project Grazing4AgroEcology (G4AE, EU funded under GA 101059626) illustrates how innovative farmers, researchers, and other stakeholders are now, at different levels, jointly exploring new approaches for sustainable grassland management to address the challenges they face.

### *5.1 The project Grazing4AgroEcology*

To enhance the sustainability and productivity of grazing in grassland-based systems, the project G4AE (www.grazing4agroecology.eu) was established to foster agroecological innovations across Europe. G4AE aims to restore confidence among farmers and the agricultural industry in the performance and competitiveness of grazing and focuses on the five principles that Dumont et al. (2013) proposed to be optimized in animal production systems: (1) adopting management practices that aim to improve animal health, (2) reducing the inputs required for production, (3) reducing pollution by optimizing the biogeochemical functioning of farming systems, (4) enhancing diversity within animal production systems to strengthen their resilience, and (5) preserving biodiversity in agro-ecosystems by adapting management practices. A cornerstone of the G4AE approach is the implementation of a multi-actor strategy, recognizing that effective innovation arises from the collaboration of diverse stakeholders. The project brings together farmers' organizations, farmers, extension services, educational institutions, and research bodies from eight EU countries. In G4AE, they jointly explore new approaches for sustainable grassland management at different levels.

### 5.2 Farm level

Digital tools can benchmark and guide agroecological performance. G4AE has introduced a digital tool that helps farmers in all participating countries assess their agroecological performance. This so-called "Grazing4AgroEcology Self-Assessment Tool" that was developed in a multi-actor approach allows farmers to monitor the agroecological performance of their farms for the five principles: animal health, reducing inputs, reducing pollution, enhancing diversity and preserving biodiversity. Other examples of innovations at farm level are precision grazing techniques, where farmers have adopted precision grazing methods, utilizing GPS tracking devices and smart collars for cattle to guide grazing (virtual fencing). These technologies help optimize grazing patterns and improve pasture management, ensuring that livestock graze in an optimal way. Also, farmers have implemented rotational grazing systems where livestock are moved between different paddocks, giving each section of the pasture time to recover and regenerate. This method improves the overall productivity of the pasture while ensuring that soil fertility is maintained and that grasslands are not overgrazed.

### 5.3 Field level

Innovations have also taken place at field level. In many European countries, multispecies mixtures of grasses, legumes, and herbs are increasingly sown. As they come with complementary traits, they can deliver benefits such as reduced fertiliser requirements, increased resilience against drought, and a more stable production throughout the year. They also benefit biodiversity. Decision-support for nutrient applications, grounded in monitoring and modelling can lower costs and environmental losses while maintaining productivity.

### 5.4 Importance of multistakeholder approaches

Because contexts differ by climate, soils, infrastructure, markets, and policy, innovations must be co-designed with those who implement them. The G4AE project illustrates how a multi-actor approach, bringing together partners from different countries and with diverse expertise, can foster meaningful innovations in grassland-based production systems across Europe. By combining scientific knowledge, practical experience, and stakeholder perspectives, G4AE strengthens both the sustainability and productivity of grasslands, while highlighting their essential role in meeting broader environmental and societal objectives. The project demonstrates that economic viability and environmental management can go hand in hand, offering pathways towards more resilient and sustainable agricultural practices across Europe.

## 6 Conclusion: Future role of grassland systems in Europe

Earlier sections of this chapter have shown that grassland-based production systems contribute substantially to a wide range of ecosystem services. Yet, several major trends, including shifts in dietary preferences, evolving environmental regulations, and economic pressures, could lead to a reduction in livestock numbers across Europe. Such a decline may, in turn, decrease the area of managed grasslands. With lower demand for grazing, grasslands risk conversion to cropland, forests, or urban areas, or may be abandoned altogether. This could reduce the land available for agricultural production and diminish grassland-specific ecological benefits, such as carbon storage, wildlife habitat, soil fertility, and water infiltration. The extent of these impacts will vary depending on context, particularly the grassland type.

While reducing livestock numbers may address certain environmental concerns, it also introduces trade-offs that must be carefully considered in future land-use and agricultural policies. Taking multiple perspectives into account, the role of grasslands is likely to grow in importance as society increasingly relies on their capacity to deliver multiple ecosystem services. One key driver is the need for animal protein for human consumption, produced with minimal input of human-edible feed. Recent research has demonstrated that strictly grassland-based ruminant systems have substantial potential to meet this goal while relieving arable land from fodder production (e.g. Pfeifer and Winterberg, 2024; Wild et al., 2025). Achieving this requires improvements in both the efficiency of grassland management and the use of grasslands in livestock systems.

Technological and societal innovations will be essential to reduce trade-offs among competing objectives and enhance overall efficiency. These include diversifying grassland swards (Komainda et al., 2024), adopting smart farming and AI-based technologies (Horn and Isselstein, 2022), and engaging stakeholders in co-creation and co-development processes. Collaboration among farmers, researchers, policymakers, and industry experts is crucial to develop context-specific, sustainable solutions.

In conclusion, grassland dynamics are shaped by the complex interplay of natural processes and human interventions, which will continue to influence their structure, function, and productivity. We believe that grasslands are set to play a pivotal role in meeting the dual challenge of feeding a growing global population while safeguarding ecosystem health. Enhancing their efficiency and multifunctionality offers a promising pathway, enabling the production of high-quality food and net human-edible protein while maintaining biodiversity, soil fertility, and climate-regulating functions.

Ultimately, a holistic and interdisciplinary approach to grassland management is needed, recognizing the interconnectedness of agricultural productivity, environmental sustainability, and socio-economic factors. This approach should be supported by science, education and policies. By fostering collaboration among stakeholders, European grasslands can continue to provide essential ecosystem services while meeting the demands of a changing world.

## 7 Research priorities

Future grasslands research will require a holistic, multi-disciplinary approach that integrates knowledge from various spatial scales, actors along the value chain, and diverse scientific disciplines. Given the complexity of grassland ecosystems and the need to address multiple challenges in food production and sustainability, research will increasingly need a multistakeholder approach – an approach that fosters collaboration between farmers, advisors, researchers, policymakers, and industry stakeholders. This collective effort will be critical in developing solutions that are both locally relevant and scalable across different regions. It is crucial to bridge the gap between different scientific disciplines. Collaborative research between natural sciences (e.g. agronomy, ecology), production sciences (e.g. animal science, agribusiness), and socio-economic sciences (e.g. economics, policy studies) will provide a more comprehensive understanding of how to optimize grassland systems. Interdisciplinary research will ensure that innovations are not only technically sound but also economically viable, environmentally friendly and socially acceptable.

Some specific research needs are as follows:

- Technical research: a key focus area will be the development and optimization of grazing systems that enhance productivity while minimizing environmental impact. Research will continue to explore genetic improvements in livestock, such as breeding for improved disease resistance and enhanced nutrient use efficiency. Advanced systems management techniques will be central to improving the efficiency of grassland-based production systems. Additionally, technological solutions, such as sensor-based technologies, will be pivotal in improving labour conditions, increasing precision in grazing management, optimizing nutrient management planning, and monitoring livestock health in real-time. Research into multispecies swards, particularly in low-nutrient environments, will contribute to boosting grassland resilience and diversifying feed sources.

- Decision Support Tools (DSTs): the development of DSTs that combine data from various sources, such as satellite imagery, soil sensors, and livestock tracking devices, will empower farmers to make informed decisions that enhance productivity and sustainability. These tools will be essential in optimizing grazing patterns, managing pasture health, managing nutrient (fertilizer) use, and improving the overall efficiency of grassland-based systems. By using real-time data and predictive analytics, farmers can adjust their practices to maximize output while reducing environmental footprints. Digital tools, such as block chain for traceability and farm management software for planning, will help streamline operations, improve transparency, and enable more precise management of resources. Research will focus on how to integrate digital solutions in a way that is accessible and beneficial for farmers, especially those in smaller or less technologically advanced farms.
- Socio-economic and policy research: understanding the socio-economic context of grassland-based livestock production will be important for creating policies that support sustainability. Research will focus on developing effective strategies to increase societal support for grassland-based systems, including premiums, labels, and certification programs that incentivize sustainable practices. Research into short supply chains, and how they can be strengthened to improve profitability and food security, will be necessary. Additionally, communicating the value of grassland-based systems to the public will be increasingly important, with research focusing on improving how these systems are perceived and understood. Transparent communication and marketing strategies will play a key role in gaining public and political support.
- Finally, one of the most pressing research needs in grassland-based livestock production is research at the systems level as grassland-based systems are complex and influenced by many factors. Currently, much of the research focuses on isolated aspects of production (such as grazing management or incentives), but there is a need for more integrated, system-level approaches that also consider socio-economic effects. Research

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at the system level requires examining how different components, such as grazing patterns, soil health, and biodiversity, interact and influence overall system performance. In addition, the role of societal interaction, good communication, and a comprehensive understanding of the broader context should be considered. This means exploring how stakeholders from science and practice, including farmers, researchers, policymakers, industry experts, and local communities, can work effectively together to share knowledge and coordinate efforts.

## 8 Where to look for further information

The European Grassland Federation (EGF) is a forum for students, research workers, advisors, teachers, industry representatives, farmers, policy-makers, and other people with active interest in all aspects of grassland in Europe. These aspects include utilization and management of all types of grasslands for production and other ecosystem services. The motto of the EGF is "*Connecting people to face the future challenges of grassland use in Europe*", and the objectives of EGF are:

- to facilitate and maintain close contact between Grassland Organizations in Europe;
- to promote the interchange of scientific and practical experience between grassland experts; and
- to initiate conferences and other meetings on all aspects of grassland production and utilization in Europe.

All papers of EGF conferences are peer-reviewed, edited and published in the proceedings that can be found at https://www.europeangrassland.org/.
Other sources of information are:

1. Encyclopedia pratensis (https://www.encyclopediapratensis.eu/). This is an online encyclopedia on grasslands built on the basis of international scientific literature and enriched by practices from farmers. It contains results of several international research projects.
2. Grassland use in Europe - a syllabus for young farmers (https://www.quae-open.com/produit/123/9782759231461/grassland-use-in-europe). The European project Inno4Grass (www.inno4grass.eu) provided an overview of grassland use in Europe, including grassland production, grazing management, hay and silage making, soil and nutrient management, environment and biodiversity, and quality of grassland-based animal products in the form of a syllabus for young farmers (Van den Pol-van Dasselaar et al., 2019). Understanding

and optimizing grassland use is key to ensuring the sustainability and resilience of European grassland farming systems in the face of environmental and economic challenges. The syllabus also provides country-specific information on grasslands in eight countries that are scattered throughout Europe (Sweden, Ireland, the Netherlands, Belgium, Germany, Poland, France, and Italy), thus providing a picture of grassland management in different pedoclimatic regions of Europe. The syllabus is currently being updated and will provide the latest insights with respect to grazing and information on grasslands in Sweden, Ireland, the Netherlands, Germany, France, Romania, Portugal and Italy.

3. Websites of European Union joint research projects on grasslands: Inno4Grass - https://www.inno4grass.eu/en/, SuperG - https://www.super-g.eu/, and Grazing4AgroEcology - https://grazing4agroecology.eu/.

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