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Systematic Review

European Permanent Grasslands: A Systematic Review of Economic Drivers of Change, Including a Detailed Analysis of the Czech Republic, Spain, Sweden, and UK

John Elliott [1], Sophie Tindale [2], Samantha Outhwaite [1], Fiona Nicholson [1], Paul Newell-Price [1], Novieta H. Sari [2], Erik Hunter [3], Pedro Sánchez-Zamora [4], Shan Jin [5], Rosa Gallardo-Cobos [4], Simona Miškolci [6] and Lynn J. Frewer [2,*]

1 RSK ADAS Limited, 4205 Park Approach, Leeds LS15 8GB, UK; john.elliott@icf.com (J.E.); samantha.outhwaite@kantar.com (S.O.); fiona.nicholson@adas.co.uk (F.N.); paul.newell-price@adas.co.uk (P.N.-P.)
2 School of Natural and Environmental Sciences, Newcastle University, Newcastle upon Tyne NE1 7RU, UK; sophie.tindale@newcastle.ac.uk (S.T.); novieta.sari@newcastle.ac.uk (N.H.S.)
3 Department of Work Science, Business Economics and Environmental Psychology, Swedish University of Agricultural Sciences, P.O. Box 88, SE-230 53 Alnarp, Sweden; erik.hunter@slu.se
4 Department of Agricultural Economics, Higher Technical School of Agricultural and Forestry Engineering (ETSIAM), University of Córdoba, Rabanales University Campus, 14071 Córdoba, Spain; pedro.sanchez@uco.es (P.S.-Z.); es2gacor@uco.es (R.G.-C.)
5 Faculty of Business and Law, School of Strategy, Marketing and Innovation, University of Portsmouth, Portsmouth PO1 2UP, UK; andy.jin@port.ac.uk
6 Department of Regional and Business Economics (FRDIS), Mendel University in Brno, 613 00 Brno, Czech Republic; simona.miskolci@mendelu.cz
* Correspondence: lynn.frewer@newcastle.ac.uk

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Abstract: Permanent grasslands (PG) feature in the European rural landscape and represent a major agricultural production resource. They support multiple non-provisioning ecosystem services (ES), including climate regulation, flood control, biodiversity, and pollination. PG are at risk of loss or degradation due to agricultural land use and land management changes. The objective of this systematic review is to identify the main economic influences shaping management and maintenance of PG, and the risks and opportunities for delivery of a range of ES. A total of 51 papers were included. Relevant policy interventions and economic drivers are identified in relation to how they shape the management of EU grasslands over time and across farming systems, countries, or biogeographic zones. A high reliance on public payments from the EU Common Agricultural Policy (CAP), with uneven impact on mitigating PG losses and associated ES provisions, was identified, which needs to be considered in relation to ongoing CAP reform. There is a gap in the literature regarding economic tipping points for change. Future research needs to identify and map ES provisions by PG along with trade-offs and synergies, and link this to policy. There are substantive challenges to maintaining Europe's PG area and management, which must be addressed through EU-wide instruments.

Keywords: permanent grassland; economic policy; Europe; CAP reform; farmers; tipping points

1. Introduction

Permanent grasslands (PG) feature in the European agriculture and rural landscapes, covering almost 60 million hectares across 28 EU Member States; in 2016[1], this represented 34% of the total Utilized Agricultural Area (UAA) in the European Union [1,2]. PGs, defined as land used for more than five years for herbaceous fodder or forage production [3], can support a wide range of ecosystem services (ESs) as part [4] of the agricultural production system [5–9]. Food production from livestock and biomass production for animal fodder or biofuel are key agricultural provisioning services from PGs [4]; other ESs include carbon

storage; diverse habitats to support biodiversity [10]; flood control; and minimization of soil erosion [11]. PGs also support soil formation, nutrient cycling, and cultural services related to landscape aesthetics, such as tourism, recreation, and heritage [12–14]. PGs are at risk of loss because of anthropogenic activities [15,16]). Across the biogeographical zones of Europe, the greater part of semi-natural grasslands has been lost since the 1940s [17–19]. Changing patterns in the extent and intensity of agricultural land use are partly driven by increasing demand for food—in particular, cheap food, commodities, and biofuels, stimulating agricultural expansion, and intensification [20,21]. This exerts pressure on grassland farming systems and ecosystems more broadly [8,22,23]. In addition to urban development, PGs in agricultural systems are under threat from cultivation, intensification, and abandonment [24,25]). Maintenance of PGs and the ES functions they deliver are at risk of sub-optimal management [26] and heat or drought stress under changing climatic conditions [8,26]). In the EU, investment in "Nature Based Solutions" and associated policies to support land management and promote ESs are understood as a source of economic development and is increasingly prioritized in agricultural financial policies such as the Common Agricultural Policy (CAP), through farming subsidies and funding [27], as well as other European agricultural policies outside of the EU, e.g., the Swiss Agricultural Policy [28] or UK Environmental Land management Schemes [29]. The Common Agricultural Policy (2021) requires EU member states to create (national level) strategic plans that encompass Green Deal priorities ("no net emissions of greenhouse gases by 2050, economic growth decoupled from resource use, no person and place left behind") [30]. However, in current policies, payments linked to agricultural production may not be effectively linked to ES delivery [27]. When evaluated in terms of policy goals, implementation costs, and impacts, the CAP (prior to reforms post-2020) has been criticized for having marginal climate or environmental impacts [6,31], as well as questionable costs–and benefits [32,33]. Similarly, national policies have been criticized for failing to deliver against environmental targets. Current CAP reforms (e.g., adopted in 2021) reflect the continuing centrality of economic policy in balancing current and future challenges (e.g., climate change and generational renewal) with financial support provided to European farmers to create a sustainable and competitive agricultural sector [30]. PG use and management is shaped by contextual factors (local conditions of soil type, land gradient, ground water level, and prevailing weather conditions), together with farm type (e.g., dairy, beef, sheep, and/or goat [34]) and farming system (organic or conventionally, intensively, or extensively stocked; e.g., [35,36]). Within these constraints, agricultural land use and management decisions made by the farmer, landowner, and/or land manager are shaped by economic drivers (business profitability and subsidies) and "productivist" values [37]. However, farmers are simultaneously influenced by socio-cultural factors, cultural expectations, attitudes to farming, family values, and routine practices, *inter alia* [38,39]. Developing policies to support and protect PGs, and the ESs they deliver, at a European regional level of governance is complicated by the large differences between countries in terms of the area of PGs (e.g., 15% in Sweden and 58% in the UK [2]), as well as variations in spatial fragmentation and distribution of PGs within different sub-regions and the broad range of environmental conditions and farming systems. Together, these disparities lead to different priorities in terms of the specific roles played by PGs in different regions and the concomitant management of grasslands. For example, northern boreal hay meadows in Sweden were abandoned during the modernization of agriculture and reverted to woodland, while southern Mediterranean grasslands (montado/dehesas) are maintained as semi-natural habitats with scattered oak trees and extensively grazed grasslands.

These disparities lead to variations in yields and, therefore, (potential) profitability [40,41] and differences in socio-economic drivers influencing management decisions. Variations in environmental value, i.e., the scope and degree of benefit [42] of PGs across Europe, also needs to be considered in EU policy design. Subsequently, the effectiveness of policies designed to support ESs broadly and PGs specifically is variable [43]. Such difficulties are evidenced by the limited capacity of regulations and policies to deliver the wide-

ranging, long-lasting changes that are required to meet EU objectives for more sustainable agricultural practices. Two challenges face European-scale economic support for the management, maintenance, and protection of PGs:

1. The encouragement of the most appropriate management of PGs across the various biogeographic zones, to cope with current and changing climatic conditions [44];
2. Understanding how the various social and economic drivers underpinning or influencing decision making regarding land management have differential impacts on PGs across regions and varying farm systems.

Decisions to cultivate or abandon PGs directly impact the delivery of important ESs [45,46]. There is a need to identify and map the social and economic "tipping points" [47], at which a series of small changes, e.g., in economic performance or policy support, become significant enough to cause a substantial change in land use or management for PGs with respect to the of provision of ESs (e.g., land abandonment, cultivation of PG, and intensification of PG systems). The objective of this paper is to present the main economic influences which shaped the management and maintenance of European PG systems under the CAP to 2019, prior to CAP reform, across several different contexts and the subsequent risks and opportunities for delivery of a range of ESs. The results of the systematic literature review (SLR) examining the link between land use and management in PG systems and economic drivers such as markets and public policies are assessed in relation to those factors that are likely to influence the economic performance, viability, or economic security of farm businesses. Implications and learnings for CAP reform will be considered. The SLR addressed the following questions:

1. What is the role of economic drivers in shaping the management of EU grassland systems?
2. What are the tipping points where land use and practice might change with respect to the of provision of ESs?
3. What is the role of public policy in shaping the economics of PG farming systems?

2. Materials and Methods

A SLR protocol was developed to identify the relevant, published peer-reviewed literature, including scientific papers and empirical datasets [48,49]. A combination of search terms (See 3) was applied to three databases (Google Scholar, Science Direct, and Scopus), followed by a screening of the results for relevance to research questions. The SLR was also supplemented by an analysis of data from the Farm Accountancy Data Network (FADN), a European system of annual sample surveys that collects accountancy data from farms on income and business activities of EU agricultural holdings [3]. The FADN data have been used to provide an overview of the economic context against which farmers' decisions on land use and management are made.

The SLR search protocol delineated relevant inclusion and exclusion criteria, defined key concepts, and identified appropriate search terms for input into the selected literature databases. The search was confined to papers published between 1962 and 2019, covering a period from the launch of CAP to the most recent lifecycle stage of the CAP prior to the expected adoption of reforms in 2020 (agreement on reform was eventually adopted in 2021), as well as policy and subsidy uncertainty in the UK related to BREXIT. Inclusion criteria included the use of empirical data collected from EU countries (which then also included the UK) and Switzerland, relevance to the research questions, English language, and peer review. A set of search terms were derived from the initial research questions using associated key words and phrases. A wide variety of search terms were used to cover the multiple contexts in which decisions about PGs could be made. Search strings were trialed and refined in a multistep process, with the face validity of each search assessed against the appropriateness of its focus in relation to the research questions. Searches were conducted in Google Scholar and replicated in Science Direct and Scopus [50]. Where there were more than 100 results in both Google Scholar or Scopus searches, the first 100 records

were downloaded and included in the review (equivalent to 10 pages of Google Scholar results), thus capturing the most relevant hits while still representing the extant literature and a feasible number of papers to screen [51]. The results of all searches were exported to a Mendeley library, combined, and duplicate or incomplete records were removed, returning a total of 2794 papers.

Following the completion of searches, the articles were screened for relevance and eligibility, using the PRISMA approach (Figure 1) [52]). The returned papers were initially screened by assessing the title and abstract against the inclusion/exclusion criteria (SO). This resulted in 484 full-text articles being identified as suitable for potential inclusion. These were then read in full, with relevant information and themes recorded, resulting in 51 papers being identified as appropriate for inclusion in the review. These were analyzed thematically in line with the research questions and relevant data were extracted. A second reviewer (ST) performed a reliability and quality check on a random sample (10%) of the papers to reach a consensus on inclusion.

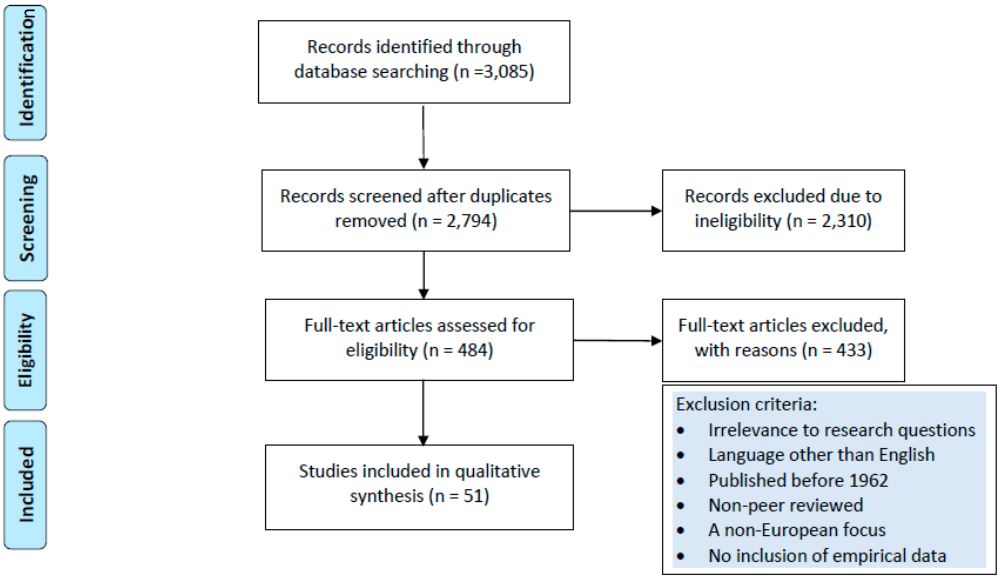

Figure 1. Prisma Flow Diagram of Systematic Review Process.

For the purposes of this research, FADN income data from the Czech Republic, Spain, Sweden, and the UK were analyzed (representing 4 of the 5 biogeographic zones outlined above; Switzerland did not contribute to FADN). Data extraction was further stratified by farm system and limited to the most recent 10-year period (2008–2017). The income data extracted was examined in terms of the following: (1) The percentage of UAA that was PG; (2) The proportion of subsidies (direct payments and other CAP payments) in Gross Farm Income. In addition, data from the most recent EU Farm Economics Overview were assessed to inform the wider context of the economic performance of EU farms. The data extracted from the FADN and the EU Farm Economics Overview provide valuable context. Furthermore, these data provide evidence of the breakdown of income streams for PG farms (balance of market returns and policy support) and tipping points for changes in PGs.

3. Results

There is an extensive literature concerned with grassland management across Europe. Research papers that focused on the role of economics in land use or management of EU grassland systems, or how public policy shapes the economics of PG farming systems, are fewer in number. Subsequently, many of the papers returned were not directly relevant to the objectives of this research, e.g., focusing on the development of economic models or the comparative analysis of grassland systems, sustainability and ES provision, and

ecological functioning. Thematically, the literature tended to focus on alpine mountain systems, dairy farms, and farming, as opposed to PGs, and its role and value in these systems. Papers ranged across biogeographic zones and farming systems with multiple methodologies applied (the most prevalent being secondary data analysis) (Table 1). Most of the papers were published post-2000 (with no relevant papers found before 1990) and reflect an increasing policy interest in ES provision from agriculture.

Table 1. Categories of papers included in SLR (number of papers for each category in brackets).

Coding Category in Thematic Analysis	Results
Biogeographic Zone	Atlantic (11) Continental (7) Alpine (6) Mediterranean (6)
Time period	1990–1999 (1) 2000–2009 (17) 2010–2019 (33)
Methodology Used	Secondary data analysis (17) Modelling (13) Policy analysis (8) Case studies (7) Survey (5) Other (1)
Farming approach	Extensive (17) Intensive (7) Organic (5) Approaches listed in remaining papers were mixed (e.g., a combination or intensive and extensive) or not stated

The literature addressing land use, management change, and the role of economics did not identify or map tipping points in land use or management for PG change (research question 3). However, broad spectrum influences in PG land use were identified, together with management changes which have occurred.

Many of the papers addressed more than one research question, with all informing research question 4 (Table 2). Given the breadth of research question 1, most papers contributed at least some relevant data or insight.

Table 2. Relevance of papers included in the SLR against each research question.

Research Question	Number of Papers Identified as Relevant to the Research Question Resulting from the Analysis
What is the role of economic drivers in shaping the management of EU grassland systems?	45
What are the tipping points where land use and practice might change with respect to the provision of ESs?	16
What is the role of public policy in shaping the economics of PG farming systems?	11
How do the above vary for different farming systems, countries, or biogeographic zones and over time?	51

3.1. PG Land Use and Management Change

The articles indicated that there have been regional differences in rates of intensification, spatial patterns of abandonment, and connectivity of grasslands across the European

Region since the inception of CAP [18,19,53]. For example, in the EEA the degree of change was illustrated by the boreal region of Norway, where from 1960 to 2015 there was a 49% loss of semi-natural grassland due to intensification and abandonment of agricultural land [18]. Similarly, a loss of 47% of studied semi-natural grasslands sites to intensification or cultivation between 1960 and 2013 was reported in England [19]. Furthermore, a breakdown of the different causes of grassland loss across the EU suggested that the most important causes of loss in the 2000–2006 time frame were conversion to arable and permanent crops (32%), followed by urban sprawl (30%) and land abandonment (17%) [33]. Abandonment was often connected to an inability to adapt land management to social and economic pressures. The cost of maintaining PGs can reach a point where farming becomes economically unviable. Limited economic viability and unintended consequences of agricultural and other land use policies also drive abandonment of marginal grasslands [54]. Despite this, some authors have concluded that, if grassland farming were not subsidized, farmers would be forced to intensify farming activities or abandon their land, especially at high altitudes [25]. However, the literature does offer examples of simultaneous intensification, land abandonment, and increased farm income; Penati et al. [24] report that dairy farmers in the Italian Alps tend to increase their net farm income by increasing their area of lowland grazing and/or their milk production per hectare in the lowlands, while at the same time abandoning highland grazing. These trajectories lead to biodiversity loss in intensified areas and loss of grassland habitats in the areas abandoned. Land abandonment appears to be more frequent in Less Favored Areas (LFAs) across Europe and is associated with challenging geographical and climate conditions leading to higher production costs [25,55,56].

Battaglini [57] reported that, in disadvantaged regions of Austria, as much as 37% of the land has been abandoned, while in Carnia (northeast Italy), nearly 67% of former agricultural areas have been abandoned [58]. The prevalence of abandonment in LFA illustrates both the role of economic drivers in PG change/management and ineffectiveness of policy tools to support PG management on less favorable land, where there is potential for high ES values due to specialist or marginal conditions.

Agricultural intensification can allow higher stocking levels and/or increase production per head, leading to improved farm income, but can also be associated with environmental problems (including loss of biodiversity) and the abandonment of marginal lands [57,59]. Hodgson et al. [60] contend that there is an exponential relationship between monetary returns and intensification of farming methods over an extremely wide range of grassland productivities and farm systems. At intermediate to high levels of soil fertility, however, the increase in financial benefit from intensification is associated with a decline in biodiversity and an acceleration in the ecological processes driving species losses from PG ecosystems. However, this "humpback" model of the relationship between PG productivity and diversity has been questioned, with some research suggesting that there is no consistent relationship between the two [10]. Importantly, physical constraints such as topography, soil type, and climate intrinsically place limitations on the amount and type of food that can be produced and on what non-provisioning ESs can be delivered. The trade-off between PG productivity and non-food ES provision represents a strong theme in the literature, with increasing production from grasslands conceptualized as a response to economic drivers [61,62].

3.2. The Role of Public Policy in Shaping the Economics of the PG Farming System

In the context of European agriculture, the CAP was originally developed to ensure sufficient, affordable food for EU populations [63,64]. The CAP is one of the oldest and most controversial of the EU policies, "characterized by large and diversified groups of beneficiaries, diversity of objectives, multi-level decision-making and an important budget" [65]. The CAP accounts for approximately 40% of the total EU budget, of which direct payments (and first-pillar market interventions) account for 74%. CAP, therefore, represents a substantial economic provision, although currently under reform.

3.3. Public Subsidy (CAP)

CAP payments to farmers aim to supplement their income, manage the supply of agricultural commodities, and influence the cost and supply of such commodities. Since 1992, and especially since 2005, the CAP has undergone significant change, with the decoupling of subsidies provided to farmers from food production. Instead, direct payments subsidizing farm income on a per-hectare basis were introduced as the main instrument under Pillar 1. These payments reward farmers for managing their land to minimum (Cross Compliance) standards for crop production, animal welfare, and the environment. In addition, farmers can access payments for environmental management, Agri-Environment Schemes (AES) and productivity grants under CAP Pillar 2, the Rural Development Programme (RDP). The RDP is designed to support rural areas of the EU in meeting a wide range of economic, environmental, and societal challenges.

Research articles reported that CAP subsidy payments represent an important element of farm incomes. For example, in the UK it was estimated that payments represented 55% of farm incomes in 2014 [66]. An Italian article on High Nature Value (HNV) farms, which include PGs and low-intensity livestock systems, similarly found that subsidies comprised more than 40% of the Net Value Added, but there was a high reliance on Pillar 2 AES and Pillar 1 LFA scheme payments [67]. The analysis of FADN data from 2008 to 2017 revealed a varied picture of reliance on CAP payments across the Czech Republic, Spain, Sweden, and UK, which was also influenced by farm type.

The FADN data supports the literature in demonstrating a significant dependence on subsidies across European grazing livestock farms. Figure 2 illustrates the reliance on subsidies (percentage of CAP payment as proportion of Gross Farm Income) expressed as a 10-year average across the regions examined. The data show that the Specialist Cattle, Specialist Sheep, and Goat farms in the Czech Republic and Specialist Cattle farms in Sweden were highly reliant on both CAP direct payments and Rural Development Program (RDP) payments (mainly AES, see below). Dependence in terms of gross income was lower in Spain overall and for Specialist Milk farms in the UK.

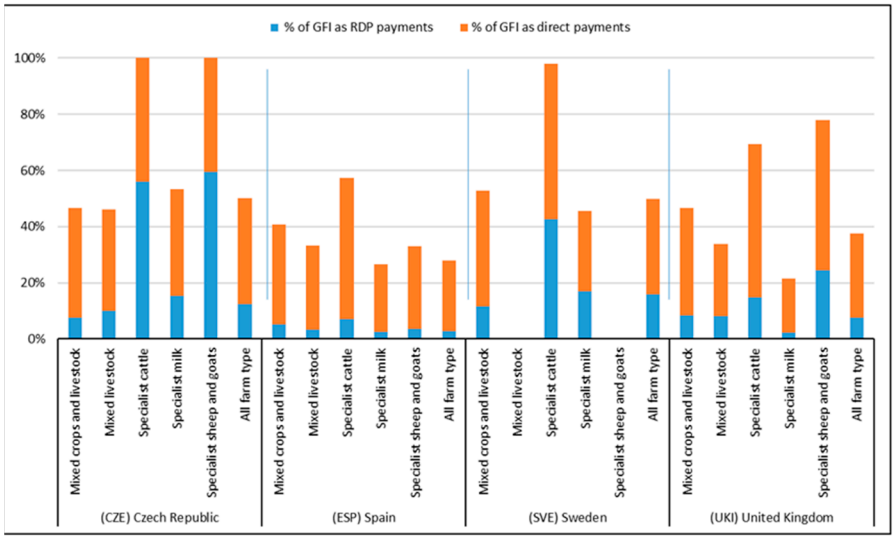

Figure 2. Percentage of gross farm income as CAP payments for the Czech Republic, Spain, Sweden, and UK grazing livestock farms (average 2008–2017). GFI = Gross Farm Income. RDP = rural development programme. Source: FADN.

The FADN data again demonstrate that farmer reliance on RDP payments to supplement income varies across countries and farm types. The percentage of Gross Income as RDP payments is generally much lower than that of the CAP direct payments (Figure 2) which illustrates the percentage of Gross Farm Income as CAP payments for the Czech Republic, Spain, Sweden and UK grazing livestock farms (average 2008–2017).

3.4. Agri-Environment Schemes (AES)

Under AES, participating farmers and land managers receive payments for the provision of environmental services through the adoption or maintenance of agricultural activities that support biodiversity, enhance the landscape, and improve the quality of the environment, which may not necessarily be optimal for profitability. A higher degree of flexibility in the second pillar of the CAP (when compared to Pillar I) enabled regional, national, and local authorities to formulate bespoke programs based on a "menu of measures" (a pre-defined set of agri-environmental measures). Importantly, this includes AES voluntary schemes, the aim of which is to encourage a balance between food production and environmental protection; these schemes represent a key mechanism by which environmental concerns are integrated into the CAP.

The direct synergies between AES objectives and farming systems, and how these align with PGs (and the ESs they provide), are identified within the literature; for example, Sawicka [68] reported that in southeastern Poland "maintenance of extensive meadows" and "extensive PG" were amongst the measures most frequently adopted by farmers. These synergies are demonstrated in the FADN data presented above, with RDP payments featuring to some degree across all the included countries and relevant farm types. As with direct payments, there is variability between countries and farm types in the FADN data and the literature. For example, several German papers reported that AES payments varied significantly in relation to land-use attributes [39,69]. This also relates to how well the farming system can accommodate the prescribed measure or action required by the AES [70]. Research suggested that AESs have been the most important policy instrument in motivating environmental improvements in rural Europe, but participation was often reported to be limited to larger commercial farms [39]. A number of studies suggested that grassland/livestock farmers are more likely to participate in an AES than arable farmers. For example, Früh-Müller et al. [69] noted a greater uptake of AESs among farmers in regions of Germany with high shares of grassland and Natura 2000 protected areas compared to farmers in regions characterized by intensive arable agriculture.

Golinski [71] demonstrated that farmers in Poland preferred lower, guaranteed payments for extensive management of meadows and pastures but avoided potentially higher payments for other environmental measures, which would have required them to commit to additional administration and implementation costs. Sawicka [68] reported that receiving payments was the main incentive that convinced farmers to join AES programs. Some researchers have suggested that participation in AES mitigates the negative impact on farm economic performance when adopting environmentally focused measures; this is limited to farms where losses can be (wholly) compensated by the subsidy payment or those which achieve higher prices for their products, such as organic farms [72]. Lastra-Bravo et al. [70] identified several key drivers of decision making, including fairness of payments, household dependency on agricultural incomes, age and education levels, the presence or absence of a successor, and the ability to make progressive changes to agricultural activities.

3.5. Less Favourable Area Payments

The LFA scheme, like AES, is part of the RDP under CAP. The LFA scheme intends to secure public benefits through the promotion of farming maintenance activities in disadvantaged areas, where land might otherwise be abandoned. As such, the LFA scheme is particularly significant in the context of PG areas that are valuable for biodiversity but is often marginal in terms of economic viability of farms, aiming to mitigate tipping points leading to land abandonment. LFA compensation payments reduced the difference between the gross farm income generated by farm businesses in less favored areas and those operating in better natural conditions. In the context of PG, this represents an economic mechanism for the mitigation of land abandonment. However, full compensation was not in place [73] meaning that the maintenance of PGs in LFA farming systems may be at risk of an economic trade-off, for example, through land abandonment.

3.6. The Role of Economic Drivers in Shaping the Management of EU Grassland System

Evidence from the UK shows that the intensity of current agricultural practices tends to be negatively correlated with the delivery of most ESs [61]. That is, as yields increase, services such as the provision of clean water, regulation of water quantities and greenhouse gases, and levels of cultural value and biodiversity tend to reduce. These relationships are not always linear, and there are situations in which agricultural production can enhance some ESs. For example, the grazing of grasslands can enhance biodiversity outcomes [74,75]. Moreover, it is also possible to enhance non-provisional ESs without significant loss of yield, such as by mitigating diffuse pollution [62]. However, economic drivers have a high degree of influence on farm decision making [76];, therefore, if increased yield reduces the delivery of other ES, it is important to look at the non-market provisions for ES and PG management.

3.7. The Role of CAP

Given the significant degree of economic reliance on CAP and national subsidies across Europe, research has identified CAP as playing an important role in shaping the management of PGs. Research applying modelling approaches suggests that the number of farmers choosing to leave farming and sell land would be much higher under simulated scenarios where CAP payments are abolished, suggesting that farmers are dependent on these payments [57]. The introduction of "greening measures", accounting for 30% of the direct payments budget in 2013, included a measure to limit the decline in EU country PG area to less than 5% and to designate the most environmentally sensitive PGs (ESPG) and protect them from cultivation. However, it has been contended that the ESPG designation was poorly targeted and that Pillar 1 support, as currently implemented, was unlikely to significantly enhance the CAP's environmental and climate performance [32]. Instead, direct payments tend to encourage farmers to continue to manage their land in the manner that they already do, as there is often no requirement to produce evidence of a change in practice to receive the subsidy. Further, CAP has not always been effective in maintaining the area of PGs in EU member states or supporting farmers on PG systems. For example, Souchere et al. [77] report negative trends in grasslands (and other crops) in northern France in relation to CAP impacts. Despite the 1992 CAP reform intended to contribute to overall grassland stabilization, Upper Normandy lost 200,000 ha of PG between 1970 and 2000. Similarly, Caballero et al. [78], in an investigation of six low-input PG livestock systems in different European countries and landscapes, found many of the farms were experiencing poor economic performance and were dependent on subsidies for survival, leading to the conclusion that better-focused policy interventions were needed.

Pe'er et al. [33] assert that the potential to maintain grassland biodiversity is undermined by incomplete mapping, lack of differentiation among regions and grassland types, and a focus on net area without consideration of continuity and connectivity of existing semi-natural grassland parcels. This suggests that, outside of designated ecologically valuable grassland (Natura 2000) sites, farmers will continue to receive subsidies whilst converting low-input, extensively managed, species-rich grassland to highly intensified, uniform, species-poor swards. Inadequacy in focus of the CAP greening measures has also been criticized by D'Amico et al. [79] in their examination of regional differences in agricultural systems across the EU. These authors argue that the proposed green rules applicable at that time were better suited to extensive and mountain agricultural systems as well as larger holdings, with intensive, small, and medium farms more likely to experience operative and economic obstacles in applying the measures. Subsequently, for these smaller farms, the implementation of environmental objectives could conflict with the aim of increasing their economic competitiveness. An evaluation of the CAP greening measures undertaken in 2017 for the European Commission DG-AGRI concluded that, overall, the measures had only led to small changes in management practices, with limited environmental and

climate impacts, and negligible effects on production or farm economic viability. Such pressures on PG are evidenced in twelve European Member states showing declines in the ratio of PG to UAA between 2015 and 2016, of which four (Cyprus, Estonia, Haut de France, and Romania) exceeded the 5% threshold [80]. Grassland subsidies may be the best instruments for improving sustainability and greening, especially where biodiversity objectives are either very limited or very demanding [81]. Barraquand and Martinet [82] developed a model to illustrate the effects that changing the level of grassland subsidy, and other factors, would have on the ecological value of PG. As the level of subsidy (i.e., the payment in euros per unit area of PG) increases so does the probability of persistence of a PG "indicator species". Moreover, Franco et al. [83] showed that including sustainability as a condition for receiving aid under the CAP can contribute to improving the economic results of traditional extensive (range) farms in Spain. In terms of supporting biodiversity, Ref. [84] reports that in Germany and other countries of Central Europe rural biodiversity is best conserved through the application of traditional land-use methods, such as low input sheep and cattle grazing. However, these are very uneconomical and can only be carried out by relying on CAP subsidies. These conclusions are supported by bio-economic modelling, which demonstrates that where biodiversity objectives are very demanding or potential outcomes are very limited. PG subsidies are the best instruments to improve biodiversity and economic sustainability.

3.8. Agri-Environment Schemes: Shaping the Management of EU Grassland Payment by Results Schemes

The literature examining payment by results (PbR) schemes (incentives paid which are conditional on specific measurable targets being met) is somewhat limited, reflecting the small number of trials and implementations of these schemes in Europe. Indeed, PbR for ES delivery are difficult to implement on account of difficulties in establishing ways to measure outputs resulting from on-farm action/changes [85]. The available research suggests that the uptake of PbR schemes may be marginal, due in part to these issues of measurability. Although these PbR schemes are targeted, there are concerns that uptake will, again, not encourage an extension in environmental land management but will simply pay for a degree of improvement in pre-existing environmental features. In the UK, for example, it has been argued that uptake would be limited to areas containing sites with species-rich grasslands and low management intensities [86].

Nevertheless, such PbR schemes offer promise in terms of ensuring positive outcomes for PG and ES delivery, as well as for a re-targeted approach to protect PGs at risk. The Ecopoint PbR scheme introduced in Lower Austria in 2001 to subsidize low-intensity farming offered ongoing, focused economic incentives to improve actual farming practices [87]. Other targeted PbR schemes have been piloted in European regions with some record of success, such as one run in a region of the Netherlands dominated by grasslands that rewarded farmers for a range of landscape and community services, including the preservation of small fields and old meadows. This pilot scheme informed Dutch government CAP negotiations [88]. There is a need for further research on how a payments-by-results approach can be applied at scale. The provision of ESs though the implementation of new policy instruments, markets, and regulation can, and has in the past, conflicted with PGs (e.g., PG land management practices may act to reduce biodiversity) [76]. However, new policy instruments can (inadvertently) conflict with objectives for PG maintenance and diversity (for example through emphasis on increased productivity), particularly as there is a demonstrable substantial economic reliance of farms in Europe on CAP subsidies. The literature supports the increasingly recognized need for farmer involvement in shaping policy, farmer "buy in" for economic support, and peer support to deliver change [89–91].

3.9. Markets and The Management of EU Grassland

A range of other economic drivers affects how farmers use and manage PG, including the operation of markets and environmental regulation. Despite the CAP including market

support measures as a key element of the policy mix to stabilize prices in the face of volatile production and trade, food prices fluctuate, presenting an economic risk to grassland farming. While regulation is aimed at improved environmental and animal welfare standards, it can add to the cost of production. Falling food prices and/or increased production costs can drive farmers towards land intensification or abandonment and can push small- and medium-sized farms out of business. This can impact on biodiversity and ecosystem health directly, through land use changes on farm, a reliance on monoculture pasture, and increased fertilizer use, and indirectly, via feed production processes and associated land conversion off-farm. Dairy farmers across Europe, for example, have little control over milk prices and, in the absence of adequate subsidies, have intensified production in response to falling prices. Subsequently, intensification of dairy systems presents a serious threat to grassland biodiversity [92]. The impact of such market instability can be mitigated through input self-sufficiency in grassland farming systems, (e.g., growing a greater percentage of forage "on farm") increasing farm business resilience, and promoting environmental benefits and/or ES provisioning [93,94]. However, where non-provisioning ESs are valued by consumers or supported by government, there is an opportunity for PG farmers to focus on increasing the value of their livestock rather than the volume. This can occur through branding of produce. Consumers may make an explicit choice to pay more, and/or government-based measures may create markets for public goods such as carbon sequestration or biodiversity.

3.10. Premium Production

The associated higher environmental benefits of organic and extensive production (e.g., direct reductions in per hectare GHG emissions associated with organic farming [95]) can be undermined if increased overseas production is used to compensate for shortfalls in domestic supply, as net emissions are greater [96]. Nicholas et al. [97] reported that, whilst organic farming schemes out-performed alternative AESs in a number of respects (e.g., food quality and safety and biodiversity), it was not possible to conclude which performed better overall or was more cost effective.

3.11. Bioenergy and Carbon Sequestration

Recent changes in demand and production efficiency have lowered pressure on grasslands and freed up some grassland areas for other uses, as well as creating economic pressure for diversification of production, including markets for bioenergy production and carbon (C) sequestration [98,99]. The current climate and energy context in the EU are dominated by concerns over environmental issues related to GHG emissions and climate change, together with the supply and security of fossil fuels. Sequestering carbon and providing biomass for renewable energy are seen as an economic opportunity for some grassland farmers.

Bioenergy (biodiesel, biogas, and bio-refineries) is an increasingly economically viable option for farmers. Indeed, surveys of farms in the late 2000′s indicated that grass silage was used as a feedstock in 50% of the agricultural biogas plants in Germany and Austria. Grass was reported to be an important crop feedstock for anaerobic digestion in Belgium and Sweden [99]. Prochnow et al. [99,100] contend that, for solid biofuel production, the market price for grass and possible subsidies for land use and feed-in tariffs are important for profitability. However, there is potential for predominantly positive impacts on biodiversity due to extensive grassland management.

Payments for C sequestration, and/or storage, are increasingly proposed as a means of preserving or enhancing the PG area and its biodiversity, whilst supporting farm economic income. The payment each farmer receives must be both a function of the amount of sequestered C that is measured and high enough to encourage a farmer to adopt

the system [101]. In an analysis of incentives for C sequestration, the best examples of C sequestration incentives combine monetary compensations with technical advice on how to manage pastures. However, sequestering additional C in PG is likely to be challenging in many circumstances, particularly in older PGs [102].

4. Discussion

PGs are a key feature in the European agriculture and rural landscape and deliver a wide range of non-provisioning ESs, but they are under threat from cultivation, intensification, and abandonment. Maintaining PGs and associated ESs is shaped by a myriad of factors that depend on the land use and management decisions of farmers and landowners/managers. Physical constraints intrinsically place limitations on the amount and type of food that can be produced and on the amount and type of non-provisioning ESs that can be delivered. Examination of economic drivers suggests the existence of trade-offs between increasing food production from existing PGs and the provision of other ESs. For example, introducing an AES could move a farm towards greater ES delivery; conversely, an increase in commodity prices or generational change could drive it towards greater reliance on income from food production, at the expense of non-provisioning ESs. Productive PGs can be sustainable with good environmental standards and outcomes, but that may be insufficient to protect more valued PG habitats. The trade-off between these depends on the context (farm system and economic resilience), conditions (topography, climate, etc.), and balance of economic drivers (food market demand, diversification income, and public subsidies) [6].

CAP policies, including direct payments, agri-environment schemes, and regulation, aim to mitigate threats to PGs in agricultural systems (cultivation, intensification, and abandonment). However more than 3 million ha of PG have been lost between 2000 and 2010 in the EU, representing a decrease of 7.2% and a continuing trend [103], potentially partly attributable to economic drivers. These suggest that grassland farmers across the diversity of PG environments in Europe are highly dependent on subsidies to mitigate economic pressures. However, the CAP has been largely ineffective in limiting the loss of many marginal grasslands and in targeting how the land is managed to optimize ES provisions. Direct payments tend to encourage farmers to do what they do already, and there is no need for them to produce evidence of change.

Farmers can change land use or intensify grassland management while receiving direct payments. Subsequently, more targeted and locally focused approaches are needed to maintain and improve the provision of ES from grasslands, especially for environmentally sensitive PGs. This is particularly important given the substantial economic reliance of farms in Europe on CAP subsidies [6].

The results illustrate the uneven impact of EU policies in mitigating PG losses, despite a high reliance on public payments from the CAP. Indeed, whilst direct payments, AES and LFA payments under CAP aim to mitigate the loss of PG and enhance ES provision; these are not always well designed and are unlikely to significantly enhance environmental and climate performance. As a result, many ESs provided by PGs in Europe continue to decline, illustrating the limitations of applying broadly-based, EU-wide instruments to very heterogeneous biogeographic zones and socio-cultural contexts. Whilst more targeted CAP agri-environment schemes may be more effective in encouraging a balance between food production and other ESs, uptake is voluntary and farmers are likely to adopt the most economically viable options, which may not deliver necessary environmental outcomes. In practice, some targeted actions are now being moved under Pillar 1 in future CAP developments such as eco-schemes. However, the development of new policy instruments can (inadvertently) conflict with objectives for PG maintenance and diversity. This indicates that there is a need for farmer involvement and peer support in shaping policy and economic support to deliver change. Many PGs are associated with valued landscapes, and this can provide opportunities for diversified income streams, e.g., from tourism and food processing, and environmental management, which can be supported by

market premiums (e.g., organic, pasture-based). However, although ES delivery may be improved through these value-adding modes of production, the broader commoditization of food markets has led to increasing pressure on producer prices and associated incentives to intensify land use and/or abandon marginal land.

Second-pillar CAP schemes, including AES and PbR, can work to mitigate these pressures and, therefore, reduce intensification/abandonment. However, AES and PbR are potentially problematic in terms of their impact due to limited uptake by farmers and land managers, difficulties with targeting potential adopters, and measurability of impacts and change. Barriers to participation may include a lack of specialist knowledge, or resistance to making infrastructural changes (including adoption of new practices or technologies) and may be particularly problematic where high complexity (which implies high economic risk for farm business) and additional fixed costs are a disincentive [104,105].

New and emerging markets for bioenergy and C sequestration offer new revenue opportunities, new economic drivers for ES provision, and incentivizing sustainable PG protection and maintenance. ES markets, created by government regulation of industry, already include C sequestration and bioenergy but are likely to extend to water quality and biodiversity. These emerging markets could lead to conflicts with PG protection and ES provision. As the impact of markets on PG protection and ES provision are largely unknown there is a need for further research, to investigate what impact an increased incentive to produce these goods and services may have across the diverse contexts of European PG landscapes. Together, environmental schemes (AES), food production and diversification (e.g., tourism) present a matrix of economic opportunities for farmers; sometimes these are competing (less food; more environment) but sometimes complementing (environment and tourism). These options allow individual farmers to identify the best approach to reach an economic and ES delivery balance that works in the context of their farming system. The themes in the literature suggest a need for context-relevant, potentially locally coordinated initiatives and coherent, joined-up policies. For example, organic farmers need appropriate scale to access markets and diversification activities require access to wider infrastructure.

There is also a need to generate greater insights into how to support PGs in marginal areas and avoid unintended effects. Specifically, with PbR schemes gaining greater attention, more research is needed to understand how these could be effectively used to support PG and ES provisions across Europe and at scale. Similarly, evidence is needed on the potential opportunities and impacts of carbon trading and bioenergy markets on PG protection and ES provisions and how payment for ESs may be linked to these wider economic opportunities at the local scale.

In terms of gaps in knowledge and future research, the review has identified that there is little knowledge regarding the economic tipping points that result in changes in land use or PG management and associated ES delivery. It is important to identify and map the point at which a series of small changes (for example, in economic performance or policy support) becomes significant enough to cause a substantive change in the area or quality of PGs (e.g., through land abandonment, cultivation of PG, intensification of PG systems, etc.). Addressing this gap in research will facilitate the empirical foundation for generating fit-for-purpose policy and understanding the tipping points that influence trade-offs/synergies between productivity and the delivery of biodiversity and other ESs.

Emerging Policy Trends

On 2 December 2021, the agreement on reform of the common agricultural policy (CAP) was formally adopted. The new legislation, initiated in 2023, paves the way for a fairer, greener and more performance-based CAP. The reforms aim to ensure a sustainable farming future in Europe, including the provision of more targeted support to smaller farms and increased flexibility for EU countries to adapt measures to local conditions. Agriculture and rural areas are central to the European Green Deal. The new CAP will be a key tool in reaching the ambitions of the Farm to Fork and biodiversity strategies (reference the EU green deal). Similarly, in the UK, the government is phasing out CAP-style direct payments

and is introducing payments for farmers to provide public goods such as environmental and animal welfare improvements. These changes are taking place during a seven-year "Agricultural Transition" period, initially planned to run from 2021. In Switzerland, similar policy ambitions are articulated within the CO act, designed to move toward net zero and reduced carbon emissions, approved in 2023. Various external (financial and non-financial) factors may act as cues which result in tipping points for farmer decision making regarding their farming practices (e.g., [106] including CAP incentives [107]). Recent CAP reforms include enhanced conditionality, eco-schemes, and second-pillar interventions, which have been designed to ensure that higher environmental and climate ambitions can be achieved. Critiques of the reformed CAP include underfunding for extensive farming systems, and conditionality that leaves some vulnerable areas of grassland to land use changes. Minor changes in agronomic practices may be incremental, but major changes are most likely to occur as a "tipping point", where a major change is characterized by a change in farming trajectory or a "transition" (e.g., [108]). Tipping points for change in farmer decision making need to be considered in policy development, particularly in the light of policy reform. These results suggest that if the subsidies pay for results there will be a strong linkage between the result (maintenance of permanent grasslands in good agronomic condition) and the payment, although this assumes that the link between the indicators chosen to verify the result and the result is well defined [109–111]. Farmer subsidies can be complemented by policies that aim to increase consumer demand for sustainable PG products, such as "pasture-fed" beef and "organic" dairy. A gap in the policy landscape is that which addresses consumer demand within the PG system.

Finally, a problem of permanent grasslands is low profitability, and so land abandonment or increased intensification may represent a way increase the economic viability. At the same time, climatic conditions (and changes in these) and the financial capacity of EU member states may influence the subsidies. As such, an important step in developing policy is the formulation of a detailed classification of PGs, which takes into account taking into account all of economic viability of farms, climatic conditions (and climate change), and the financial capacity of EU member states to subsidize PG lands. These factors can then be taken into account in policy development.

5. Conclusions

There are substantive challenges to maintaining Europe's PG area and sustaining or improving its environmental condition, which cannot be addressed adequately through EU-wide instruments. In addition to economic drivers, climate change may make some PG landscapes into potentially productive croplands, while in other areas the risks to PG productivity are increasing through exposure to drought, flooding, and higher temperatures. This may in turn imbue economic drivers with greater weight and alter any potential tipping point scenarios, both positively and negatively. Whilst this has been recognized to some extent in the design of the next phase of CAP (post 2020), the range and extent of ESs delivered by PG in Europe continues to decline and better evidence on effective policy responses is needed urgently.

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Notes

[1] The most recent data is from 2022 for EU-27, with PG occupying 32% of the utilised agricultural area, Eurostat. (2022). Utilised agricultural area by categories, Data Browser. [Online]. Available at: https://ec.europa.eu/eurostat/databrowser/view/tag00025/default/table?lang=en (accessed on 11 January 2024).

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