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Assessing the impacts of EU agricultural policies on the sustainability of the livestock sector: a review of the recent literature

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Abstract

How do agricultural policies in the EU need to change to increase the sustainability of livestock production, and what measures could encourage sustainable practices whilst minimising trade-offs? Addressing such questions is crucial to ensure progress towards proclaimed targets whilst moving production levels to planetary boundaries. However, a lack of available evidence on the impacts of recent policies hinders developments in this direction. In this review, we address this knowledge gap, by collating and evaluating recent policy analyses, using three complementary frameworks. The review highlights that recent policy reforms, and especially those of the Common Agricultural Policy, have had a large impact on the sustainability of the livestock sector by contributing to intensification and simplification. This has often resulted in negative impacts (e.g. on greenhouse gas emissions and animal welfare) and while financial support has enabled production, it can also lead to a culture of dependency that limits innovation. At the same time, a lack of regulation and concrete targets, and low levels of stakeholder engagement in policy design have led to delays in the delivery of sustainability objectives. Future policies could take on-board more innovative thinking that addresses the interrelatedness of society, animals, and the environment, to deliver effective targets and support.

Keywords Livestock · EU policy · Sustainability · Environment · Subsidies · Common Agricultural Policy (CAP)

Abbreviations

AEM	Agro-environmental measure
CAP	Common agricultural policy
CORDIS	Community Research and Development Information Service
EFA	Ecological Focus Area
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GHG	Greenhouse gas

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HNV	High Nature Value
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
SAFA	Sustainability Assessment of Food and Agriculture Systems
SDGs	Sustainable Development Goals
UK	United Kingdom

Introduction

Over the last decades, the EU livestock sector has been subject to profound changes regarding its structure, market and environmental conditions, consumer expectation, and regulation. Despite these changes and an increasing number of legislative and normative developments, livestock in Europe is still far from a sustainable state (Guyomard et al. 2021).

Greenhouse gas (GHG) emissions from agriculture made up 10% of the EU-28 total in 2017, and over 80% of agricultural GHG emissions are from livestock (ibid.). Regionally concentrated livestock production also leads to water and air pollution, although the total livestock population in the EU declined by 8.9% between 2001 and 2020 (Eurostat 2021). At the same time, livestock farming provides employment on farms and in related sectors, representing 36% of the total EU's agricultural industry's output in 2021, while supporting food security and human nutrition (Albaladejo Román 2023).

When reflecting on the future of animal production and enabling policies in Europe, it is necessary to consider the impacts on economic, environmental, and social domains. Moreover, to develop strategies that open just and successful paths for approaching sustainability in the livestock sector, it is necessary to understand how past policies have impacted farmers, farming systems and production structures. This is crucial for informing effective agricultural strategies that need to consider how measures may affect farming practices, environmental outcomes, farm viability, and human and animal wellbeing.

For this reason, a structured review of peer-reviewed literature on the impacts of EU agricultural policies affecting the livestock sector was carried out to identify gaps in knowledge and policy, while informing decision-making and future research directions.

Review structure and concepts

The review uses three complimentary concepts to assess the impacts of policy on the livestock sector: Sustainability Trade Offs as outlined in the FAO Sustainability Assessment of Food and Agriculture systems (SAFA) guidelines (FAO 2014), the One Welfare approach (Pinillos et al. 2016), and the Leverage Points concept (Abson et al. 2017).

The SAFA guidelines (FAO 2014) provide a framework for assessing the benefits and trade-offs of agriculture and food system practices on different sustainability issues. The guidelines are organised under the broader categories of environment, social, economy and governance, which are used for structuring the results of the review. These are further distinguished into themes and sub-themes with formulated sustainability objectives and indicators to measure sustainability criteria. Over the last years, the guidelines have been used to study the impact of livestock systems in various contexts (Cammarata et al. 2021; Pérez-Lombardini et al. 2021; Niloofar et al. 2023). The range and structure of indicators within SAFA provides an overarching reference point for structuring the analysis.

Complementing the One Health concept, which underlines the strong connection between animal and human health, the One Welfare approach relates the wellbeing of animals to that of humans and recognizes their interconnections with the environment (Pinillos et al. 2016). Considering these interactions makes it possible to detect and capitalize on direct and indirect benefits of one dimension on the other and thereby enables a holistic way to increase both human and animal welfare on a global scale (ibid.). Adding this concept to the analysis is justified due to its focus on the interconnected nature of policy implications which helps to uncover siloed thinking by considering the analytical categories animal welfare, human wellbeing and environmental conservation.

The third concept is that of "Leverage Points" , which builds on the ideas of Meadows (1999) who described twelve points to intervene in systems to bring on change. These points differ in their ability to change different layers of the system and are thus more or less effective to truly transform prevailing structures. Abson et al. (2017) further developed this thinking by defining three areas of deep leverage, which were used for analysis in this review: re-think, re-connect and re-structure. Re-think questions the generation, sharing and perception of knowledge to overcome path-dependencies based on institutionalised knowledge. This includes considering how goals for sustainability transitions are derived from available information, as well as scrutinizing "existing perceptions of legitimate knowledge in science and politics" (Abson et al. 2017, 35). Re-structure concerns the relevance and role of institutions and institutional failure or decline in bringing about system change (Abson et al. 2017). This addresses informal institutions such as customs or codes of conduct, and formal institutions such as regulations and laws (i.e. written rules) and contracts or plans (i.e. agreements) (ibid.). Re-connect refers to the potential for sustainability transitions that arise from a reconnection of people with the natural world, including how it is valued, perceived, and interacted with, and how much it is understood as crucial for

human life and wellbeing (ibid.). Furthermore, Abson et al. (2017) emphasise that a willingness to act more sustainably within a system is only possible when its design and linked institutions are changing simultaneously (Kaiser et al. 2010).

Combining these three concepts allows us to consider sustainability aspects from different lenses and at different scales. While SAFA gives us a clear framework for classifying the impacts on different sustainability dimensions and thereby helps us structure the assessment, the One Welfare concept encourages a consideration of the interplay between different sustainability dimensions. Finally, the Leverage Points approach extends the scope of the analysis from the current state to the drivers and barriers of system change, and thus helps to see beyond "what is".

Through an application of these three complementary guidelines and frameworks, this review addresses the following research questions: i) How is sustainability defined in analyses of policies for livestock systems?, ii) What mechanisms of EU agricultural policy are impacting the livestock sector?; iii) What are the impacts of EU agricultural policies on the sustainability of the livestock sector as discussed in policy assessments? and iv) What reasons for failure and/or delays in reaching sustainability objectives in the livestock sector are given in recent policy assessments?

Methods

A structured review of the published literature was carried out in 2021-2022. The method was informed by the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines and the framework for systematic literature reviews in agricultural sciences proposed by Koutsos et al. (2019).

A review protocol detailed the background, objectives, and research questions and possible search term combinations (Fig. 1) and inclusion/exclusion criteria (Table 1).

Searches were performed on Web of Science and CORDIS using Boolean operators (Supplementary Materials Tables S1 and S2). Initial searches identified 1866 publications (Fig. 2), which were filtered to exclude studies published before 2012. This was considered an important point, as the United Nations Conference on Sustainable Development - birthplace of the Sustainable Development Goals (SDGs) - took place in 2012. Moreover, the 2013 CAP reform potentially changed the impacts of policies on the livestock sector as well as their interpretation (Nègre 2022).

Upon including the filtered references in a common file, duplicates were removed. This left 1085 sources for screening. The initial round considered titles and abstracts and removed another 841 publications, based on their relation to the

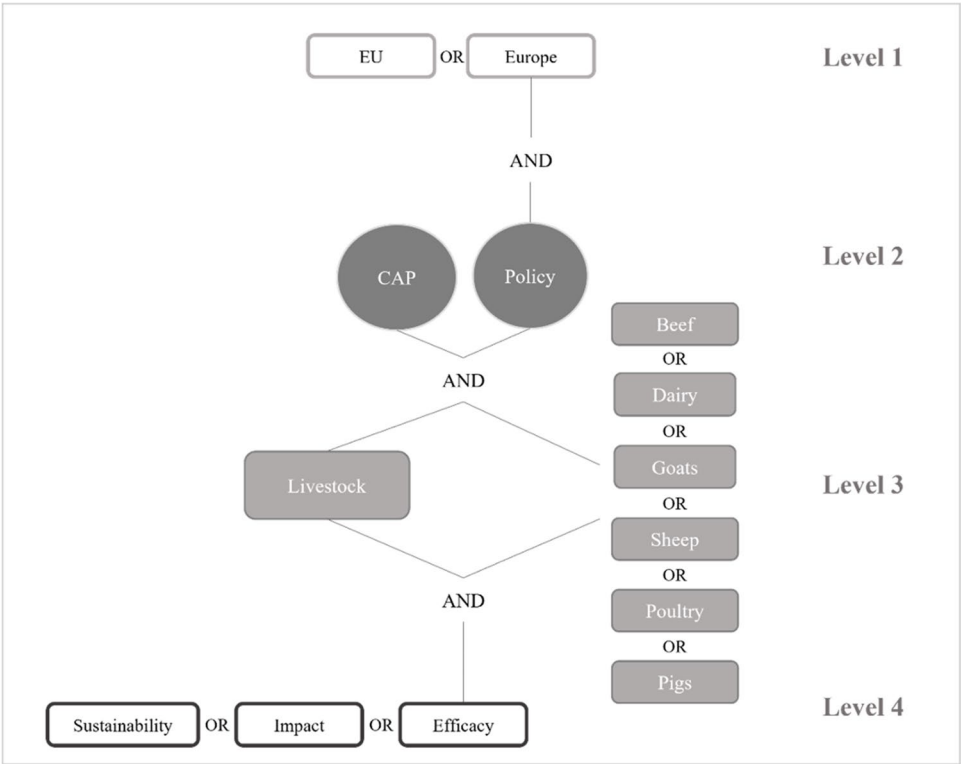


Fig. 1 Combinations of search terms used for literature identification

Table 1 Eligibility criteria for literature screening

Inclusion criteria	Exclusion criteria
Publication topic within the geographic scope of the EU (including UK before Brexit)	Publications on countries outside the geographic scope of the EU, Switzerland, or the UK
Articles published in peer-reviewed scientific journals	Publications that have not undergone a peer-review process (e.g., books, proceedings, reports)
Publication focuses on impacts of policies	Publication does not relate to policies
Publication focuses on impacts on the livestock sector, sub-sectors or individual livestock systems	Publication does not focus on impacts on the livestock sector, sub-sectors or individual livestock systems but other agricultural sectors or farming in general
Published in 2012 or later	Published before 2012
At least half of the data used in the publication is collected after 2012	Less than half of the data used in the publication is collected after 2012
Published in English	Published in a language other than English

research topic (n=378) and/or focus on impacts of (EU) policies (n=297). The second screening round eliminated a further 175 sources beyond the scope and timeframe of the study. A total of 60 sources were selected for final inclusion (Fig. 2).

The remaining 60 studies were analysed using a framework that combined research questions from the review protocol and the analytical dimensions of the One Welfare (Pinillos et al. 2016), Leverage Points (Meadows 1999; Abson et al. 2017) and SAFA concepts/guidelines (FAO 2014) (Supplementary Materials, Tab. S3). Text excerpts from the studies were collected under each analytical dimension in Microsoft Excel. These excerpts were then combined for each analytical dimension and manually coded in the qualitative data analysis software NVivo 12, further differentiating the former dimension into 39 codes. In total, 669 codes were collected, which were grouped and analysed for emerging topics and narratives.

Results and discussion

Of the 60 studies included in this review, over 80% were published between 2019 and 2022 (Supplementary Materials, Fig. S1), aligning with the aim of focusing on recent developments. Classifying sources by region and livestock type shows an imbalance in study areas within the EU (and UK prior to Brexit) (Supplementary Materials, Fig. S2) but a more even spread across livestock types (Supplementary Materials, Fig. S3). Many studies did not focus on single or multiple countries, but analysed policy impacts on an EU level (n=14). A detailed description of studies per country and livestock species is included in the Supplementary Materials.

How is sustainability defined in analyses of policies for livestock systems?

Only a few studies include a specific definition of sustainability (Table 2). While this is likely to be related to difficulties in defining the term (Creemer et al. 2019), it may also be linked to the concept's ubiquity, which suggests it is well understood. Furthermore, many papers only consider some aspect(s) of sustainability, e.g., economic and/or environmental (e.g., Alexandri et al. 2020; Bonazzi et al. 2021; Larkin et al. 2019). It is less common to consider social impacts only (e.g., Bertolozzi-Caredio et al. 2020), as they tend to be addressed more in combination with economic factors (e.g., Belanche et al. 2021; Ragkos et al. 2017) (Table 2).

Instead of including a definition of sustainability, many papers refer to non-sustainable practices within the livestock sector such as heavy grazing, conventional tillage and short crop rotations (Lessire et al. 2019) or goals of conservation or rural development that are connected to sustainability (Schermer et al. 2016; Pavić et al. 2020). Many papers also work with the Ecosystem Services concept (e.g., Muñoz-Ulecia et al. 2021; Schulte et al. 2019) whilst one study uses the "social-ecological resilience" concept to understand interactions between social and environmental aspects (Schermer et al. 2016). In this, the ecological understanding of resilience as "the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function" (Walker et al. 2004, 1) is recognised to be influenced by external social forces.

The papers that do define sustainability typically use descriptions that encompass the three dimensions of social, environmental and economic aspects (de Olde et al. 2017; Rodríguez-Rigueiro et al. 2021) and stress the need to advance in all three areas at the same time (Creemer et al. 2019).

The concept of "sustainable intensification" is also used in some studies, with regard to the trade-offs between production and environmental impact (Läpple and Sirr 2019; Gaudino et al. 2018; Burgess and Rosati 2018). Others stress the need to shift the focus from farms and farming practices to a food-system perspective (Creemer et al. 2019) and the

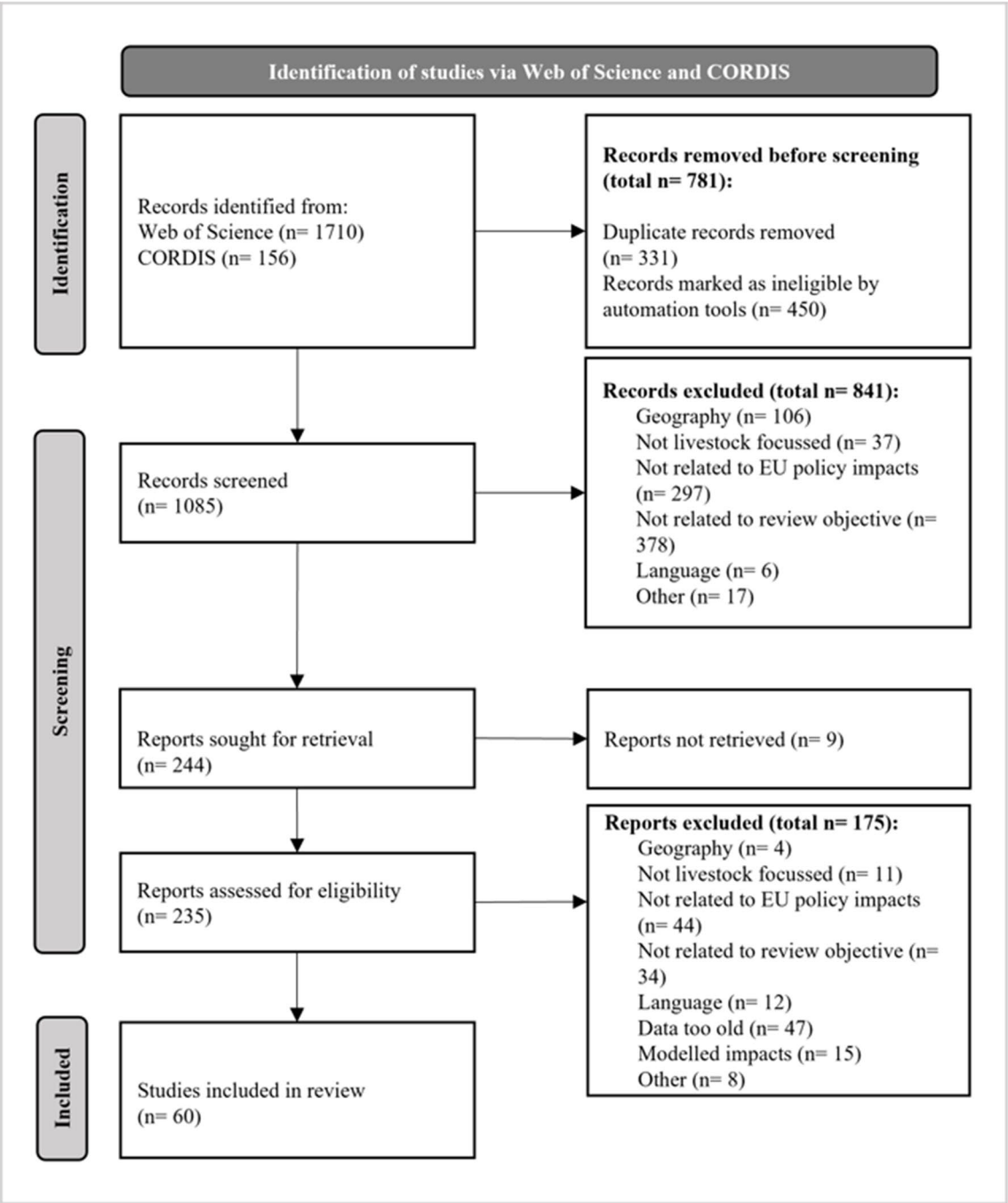


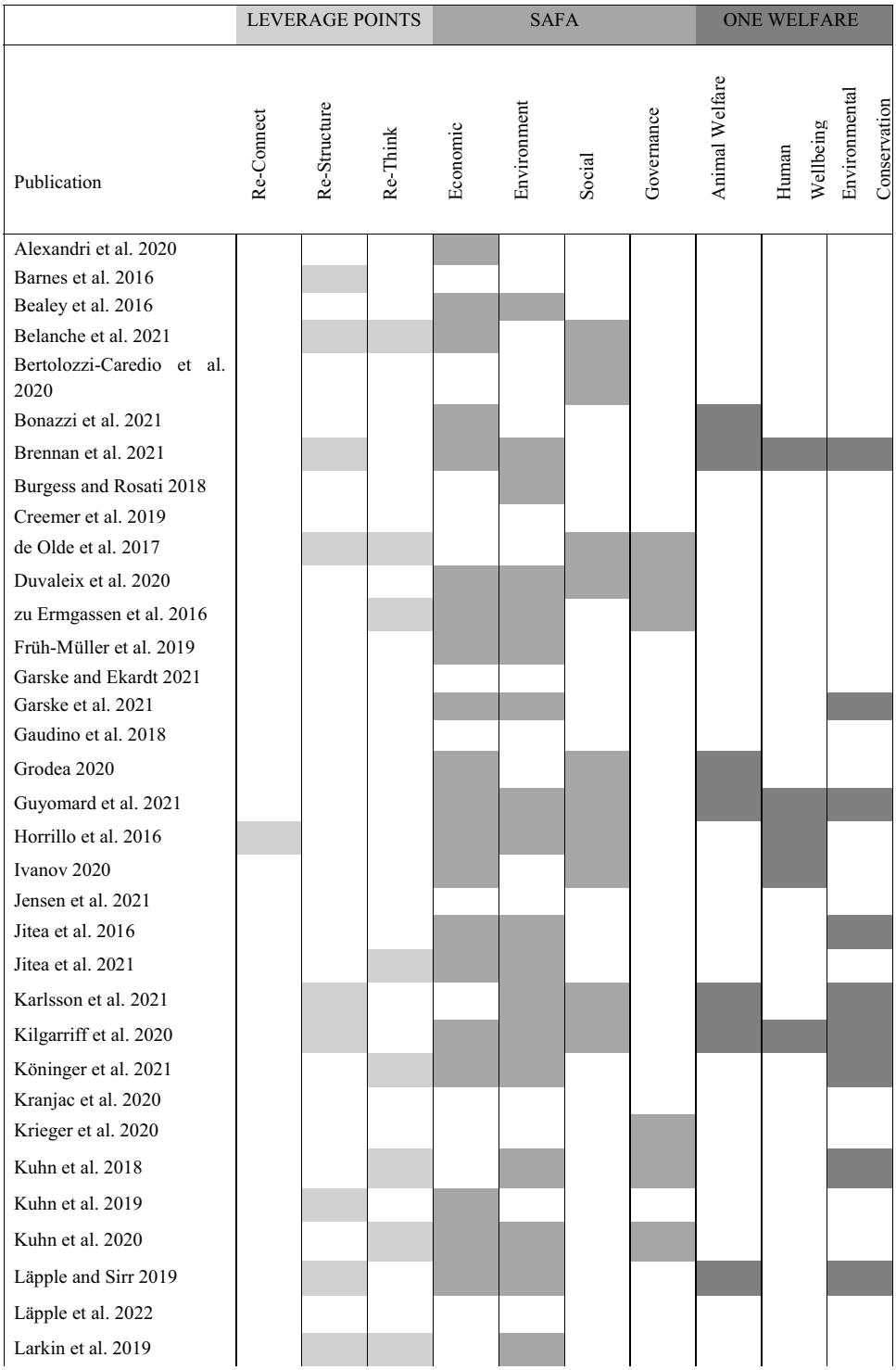
Fig. 2 PRISMA 2020 flow chart of the literature search and screening (Page et al. 2021)

importance of alignment with global goals (Stubenrauch et al. 2021; Burgess and Rosati 2018).

What mechanisms of EU agricultural policy are impacting the livestock sector?

The Common Agricultural Policy (CAP) is widely discussed for its influence on the environment, farm income and production structures (Gaudino et al. 2018; Martinho 2022; Popovici et al. 2021; Horrillo et al. 2016). This influence is the result of mechanisms, that impact the evolution of farming systems. CAP reforms have, in-particular, decreased the level of market interventions (e.g., dairy quotas) in favour of open markets and increased support payments for environmental measures, but also to support livestock farmers, who benefit disproportionately from CAP-based

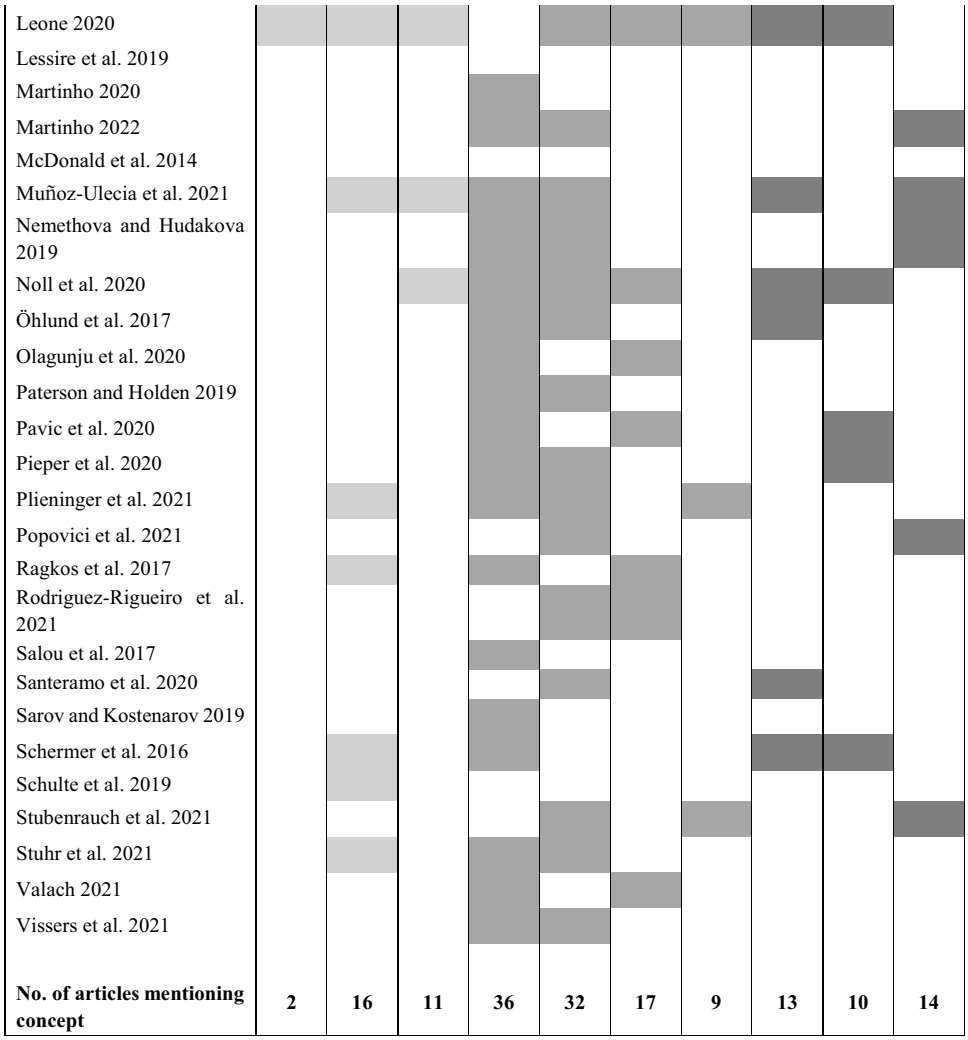
Table 2 Identified literature and representation of sustainability themes



payments for farms in disadvantaged regions (Belanche et al. 2021; Larkin et al. 2019; Némethová and Hudáková 2019; Guyomard et al. 2021).

The positive relationship between farm size and payments received was identified as an important influencing factor on agricultural expansion and intensification (Guyomard et al. 2021; Alexandri et al. 2020; Plieninger et al. 2021). Authors of a study of Scottish livestock farmers concluded that their findings "seems [sic] to infer that payments are not as decoupled as policy makers would wish" (Barnes et al. 2016, 556). Yet, other factors such as the existence of a successor were also found to have significant effects on the intent to increase or decrease production despite hypothetical changes in CAP payment rates (ibid).

Table 2 (continued)



Studies also show that the viability of many farms depends on receiving CAP payments (Muñoz-Ulecia et al. 2021; Guyomard et al. 2021). Guyomard et al. (2021) highlight that subsidies representing 57, (dairy), 85 (sheep and goat) and 133 (cattle) percent of farm incomes were paid in the EU in 2018, with the lowest share of income (30%) being paid to pig and poultry farms. While this support could give farms the economic space to implement changes to increase sustainability, the high subsidy share of incomes has shown to create stagnation (ibid.).

It is thus not surprising, that the distribution of payments across farms is still determined by farm size rather than ecological impact (Scown et al. 2020). This incentive to increase the size of farm holdings (Guyomard et al. 2021) is further driving land concentration and production intensification. To address this, and further incentivise the implementation of farming practices with lower environmental impacts, the new CAP (2023-2027) includes the introduction of voluntary "eco-schemes" of beneficial practices. Simultaneously, the current obligatory greening and cross compliance will form part of a "conditionality" with increased environmental requirements for receiving direct farm payments (European Commission 2022a; Meredith and Hart 2019).

Farmers implementing environmentally friendly practices that go beyond the conditional obligations for direct farm support can receive payments under Pillar II of the CAP to compensate for lost income and costs incurred (Schulte et al. 2019). Participation in any schemes under pillar II is voluntary, yet they can be critical for farms' viability, in cases of revenue and income depending on payments under agro-environmental schemes (Jitea et al. 2016). The new CAP (2023-2027) provides environmental measures both as parts of pillar I (eco-schemes) and pillar II (Agri-environment-climate measures), which may be explained by being able to providing more money for environmental activities without having to transfer budget (Schulte et al. 2019). In addition, animal welfare is strengthened in the new CAP reform, by including it both in conditionality requirements (Leone 2020) and as parts of eco-schemes under pillar I (European Commission 2022a).

In addition to payments, farmers are supported by the EU through different aids for the development of short supply chains or certified quality schemes (Guyomard et al. 2021). Higher incomes can also be achieved by changing to an organic system, e.g., by receiving organic subsidies from the EU and higher prices from consumers, yet this often involves the development of new marketing channels and also needs to be viewed in the light of increasing prices for organic inputs or additional infrastructure (Horrillo et al. 2016) and potentially lower and more variable yields (Knapp and van der Heijden 2018; de la Cruz et al. 2023). While ensuring that imported agricultural products fulfil equivalent safety standards to domestic products and thereby protecting EU producers from fraud and competition with lower standard produce, EU food safety policies can also put a strain on trade relationships where there is disagreement between trade partners, e.g. on health effects of certain practices banned in the EU (Guyomard et al. 2021). Simultaneously, tariffs, e.g., on bovine meat imports, also contribute to keep domestic price levels high by regulating less expensive competition from third countries (ibid). Additionally, different directives (e.g., Nitrates Directive, Water Framework Directive) set out specific targets and allowances that (livestock) farmers must comply with as parts of national legislation (Köninger et al. 2021). Formulating Strategic Plans for each Member State as set out for the new CAP period is considered useful for increasing the environmental sustainability of farming systems as these plans are able to translate national targets, e.g. on carbon sequestration or nitrate emission reduction, into measures under schemes that are more specific to and targeted towards the national and regional contexts and areas of concern of Member States (Schulte et al. 2019). However, the challenge of making uptake of practices attractive to farmers remains despite their potentially greater relevance (ibid.).

What are the impacts of EU agricultural policies on the sustainability of the livestock sector?

The reviewed papers cover a wider range of sustainability topics, with a focus on the economic and environmental domains, and less on social or governance aspects (Fig. 3). While sustainability debates initially focused on ecological and economic concerns (Leal Filho et al. 2022), some progress was made to increasingly include the social dimension in the concept and study of sustainability in the agricultural context (Janker et al. 2019). However, a lack of agreement of what social sustainability in agriculture entails and how it should be measured (Janker and Mann 2020) could complicate increasing research activities in this area.

The following description of impacts gives a detailed account of how these themes are represented in the different papers reviewed. While there is some overlap in papers covered under the SAFA "environment" and "social" categories with the One Welfare categories of "environmental conservation" and "animal welfare", analysis of the One Welfare concept is focused more on the interactions between aspects rather than the categories themselves. Studies that could be related to the leverage points concept were represented least. Notably, only two papers deal with "re-connection", while more address the realms of leverage "re-think" and "re-structure" (Table 2, Fig. 3).

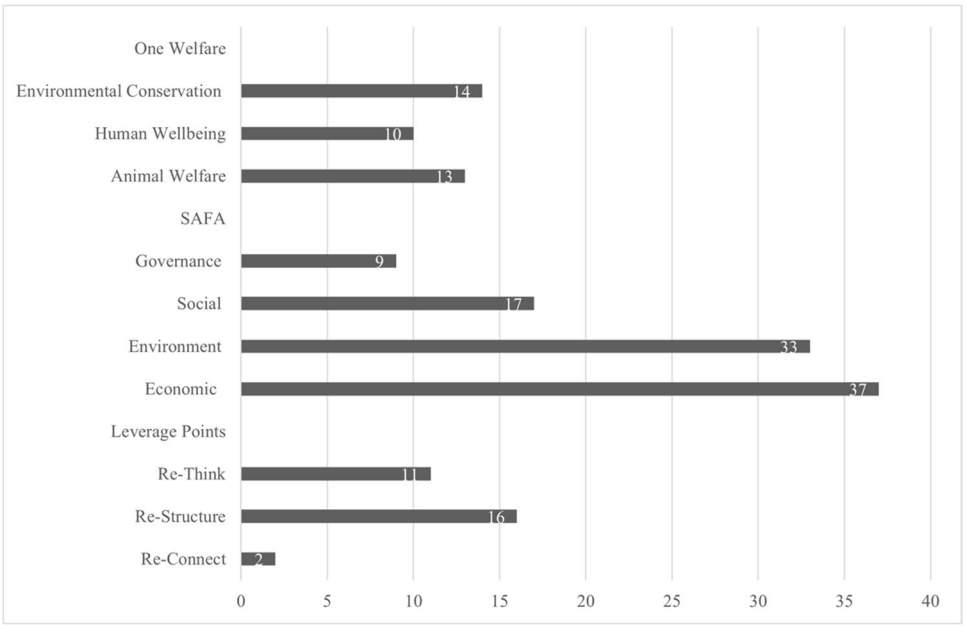


Fig. 3 Frequency of reviewed categories covered across all reviewed papers

Environmental impacts

Since the CAP regulates most of livestock production on an EU level (Guyomard et al. 2021), it is not surprising that impacts of the CAP and related payments make up a large share of the studies relating to environmental outcomes of policies.

Land use and soil quality As a result of CAP reforms and market changes decreasing viability of farming operations (Horrillo et al. 2016), many extensive systems have experienced an intensification of production and thus an increased risk of environmental degradation (Läpple and Sirr 2019; Noll et al. 2020; Horrillo et al. 2016). Intensification processes include an increased use of external inputs, changes in grazing and pasture management and increased stocking densities (Plieninger et al. 2021). This is linked to payment rates for Agro-Environmental Measures (AEM) being too low to stimulate uptake especially in intensive livestock production areas (Früh-Müller et al. 2019). Even systems such as organic farming, which are considered to increase soil quality and decrease pollution (Popovici et al. 2021) can have negative impacts on soil quality due to legislative omissions in restricting the use of conventional manure in organic systems (Köninger et al. 2021). This may have environmental consequences for soil biodiversity, e.g. when introducing heavy metals, micro plastics, or antibiotic gene resistance (ibid.). Another way of mitigating negative impacts of livestock, e.g., on soil pollution and damage due to overgrazing, could be mitigated by reducing livestock numbers (Némethová and Hudáková 2019).

Water and air quality The main directives focusing on improving and protecting water quality are the Nitrates Directive (91/676/EEC) and the Water Framework Directive (2000/60/EC) but there are also different agri-environmental measures that can help limit negative water quality impacts related to livestock farming. Kilgarriff et al. (2020) report that the exclusion of cattle from watercourses is a cost-effective measure to reduce pollution, stressing the need for a targeted approach in the post 2020 CAP. While particularly intensive farms can improve water quality in areas of high pollution, those farms could also face relatively high cost for measures to comply with regulations (Kuhn et al. 2020). As this is an incentive for non-compliance, support measures should sit alongside enforcement activities (ibid.).

Policies enabling the transport of manure from regions of high supply to low supply are another option for lowering nutrient loads (Kuhn et al. 2018). This is also relevant with regards to an intensification in dairy farming, and the associated impacts on eutrophication, acidification and greenhouse gas emissions (Paterson and Holden 2019), as, for example, observed in Ireland and the Netherlands after the milk quota was removed in 2015 (Läpple and Sirr 2019). Manure transport reduces global warming potential, freshwater and marine eutrophication, mostly as a result of better efficiency in using nutrients in the exporting and replacing chemical fertiliser on the importing farm (Kuhn et al. 2018). Yet, this positive effect is only sustained if the exporting farms do not need to use manufactured nitrogen fertiliser as a consequence of manure exports (ibid.). Enhanced leaching on farms importing manure suggests that policy makers should limit manure imports within regions facing high levels of pollutants (Kuhn et al. 2020). Policies of the Green Deal are also stimulating research on manure management with the European Commission aiming to decrease nutrient losses by 50% (Köninger et al. 2021).

Greenhouse gas emissions and biodiversity Läpple et al. (2022) found a significant reduction of emission intensity between the milk quota to post-quota phase (2000 to 2017), possibly because of the negative relationship between productivity and GHG emission intensity. Poor animal health has a negative impact on the productive lifespan, culling rates (Hristov et al. 2013) and animal performance (de Boer et al. 2011), which increase production inefficiencies and per kg GHG emissions (Llonch et al. 2017; Bell et al. 2011). Creating stress-reducing environments and handling routines and improving animal health thus has the potential to improve emissions efficiencies of livestock systems (Llonch et al. 2017). Furthermore, it was shown that compensating farmers for improved housing conditions has the potential to reduce GHG emissions (Santeramo et al. 2020). This is especially the case where this improvement resulted from the reduction in livestock numbers, which has previously been discussed with regards to its positive effect on GHG reductions (Garnett 2009; Pieper et al. 2020).

There is mixed evidence on the impact of livestock on biodiversity. Bealey et al. (2016) conclude that planting trees downwind from livestock housing and manure and slurry storage facilities, or using trees as shelter for animals have the added benefit of decreasing ammonia emissions, as trees are capable of capturing gases and particulates in their canopies. Another study highlighted that Irish farms were exceeding targets to retain areas of wildlife habitat, mostly through linear features and semi-natural woodlands, which amounted to almost 10% of agricultural holdings for intensively managed farms (Larkin et al. 2019). Yet, authors stressed that this does not give an indication on the quality of habitats and the biodiversity they are able to support (ibid.). Since extensive systems can have a positive impact, e.g. in the Dehesa or High Nature Value (HNV) farming systems (Horrillo et al. 2016; Santana et al. 2017), intensification processes and land abandonment are considered as threats to biodiversity in HNV farmland areas (Jitea et al. 2021).

In this regard, support payments are viewed as important in ensuring economic sustainability of biodiversity promoting systems (Jitea et al. 2016; Burgess and Rosati 2018), yet, Köninger et al. (2021) underline that current CAP protection and enhancement measures for soil biodiversity (e.g., through eco-schemes or agri-environment-climate payments) are mostly voluntary and may thus not be used even though they could have substantial impact in vulnerable nature areas. At the same time, measures need to be planned to suit regional conditions. For example, in Ireland, the ecological focus area (EFA) measure has been successful in rewarding the retention of landscape features that are uncommon or absent in other European countries. However, the narrow focus of this initiative might risk losing ineligible yet valuable habitats (Larkin et al. 2019).

Social impacts including animal welfare

Food security While food security is a stated objective of the CAP (Schulte et al. 2019), heterogeneous conditions between countries, affecting the competitiveness of farmers and value chain actors, can impact self-sufficiency (Némethová and Hudáková 2019). Supporting the production of protein crops in the EU could minimise import dependencies and increase feed self-sufficiency by EU farmers (Jensen et al. 2021).

Identity and succession Farming may be perceived as a desirable lifestyle worth continuing, even if it becomes economically unviable, due to non-monetary advantages (Olagunju et al. 2020) such as a sense of independence and pride in owning a business (Key and Roberts 2009). In this case, decoupled payments are helpful as they allow farmers to maintain a farming lifestyle (Olagunju et al. 2020; Schermer et al. 2016). Combining on- and off-farm income is another option for continuing traditional farming practices, yet there is also a need for ensuring the culturally and socially desirability of these practices in order for farmers to perceive them as worth maintaining (Schermer et al. 2016). With regards to succession, low average incomes (Noll et al. 2020), high costs of investments to comply with legislation and the administrative load related to receiving direct payments (Schermer et al. 2016) were some of the reasons authors quoted for preventing next generations from continuing farming.

Knowledge and skills A lack of knowledge or understanding of practices or biological processes is cited as an obstacle for complying with EU legislation. Therefore, training related to environmental protection, food safety and animal welfare becomes an important factor for the implementation of policies (Grodea 2020; Köninger et al. 2021). Despite the importance of incorporating local knowledge in decision making (Plieninger et al. 2021), authors also stress the need for improving assessment methods, and data availability, e.g., through annual sampling of farm statistics (Kuhn et al. 2020, 2018; Karlsson et al. 2021; Scown et al. 2020; Muñoz-Ulecia et al. 2021). Collaboration and inclusion of stakeholders including civil society and authorities is considered another way to develop innovative solutions suited to local demands (de Olde et al. 2017; Jitea et al. 2021; Leone 2020).

Public opinion While a share of European consumers are questioning how acceptable it is to produce animal products under current systems (Guyomard et al. 2021), farmers' awareness of how the livestock sector is viewed by the public is increasing (Lessire et al. 2019). Reconnecting people with nature can enable changes to perception of the natural world and humans within it (Abson et al. 2017). While it can be strongly questioned if this can be applied to current livestock systems, changes to values and world views are still understood to convey the highest potential for levering change, although these aspects are notoriously difficult to influence (ibid.). Only a limited number of papers addressing this re-connection may reveal a lack of ideas and enthusiasm for changing perceptions and meaning of animals in the food system but could also have been influenced by methods used in this review.

The debate on re-structuring on a larger regulatory scale as well as shifting the underlying norms, e.g., of the value of animal lives or nature, could be supported by considering a re-connection of people with the natural world positively impacting environmental protection and biodiversity (Ives et al. 2018) in discussions on the future of livestock systems. Shifting underlying norms is also linked with discussions on possible reductions of livestock numbers and changes towards a plant-based diet for reducing negative environmental and animal welfare impacts (e.g., Karlsson et al. 2021; Guyomard et al. 2021), that go as far as an emissions trading system for livestock products to link livestock numbers with GHG emission targets (Stubenrauch et al. 2021).

Legislative instruments such as product labelling could increase transparency of animal production systems and create incentives for certain practices, e.g. linked to animal welfare (Leone 2020). Introducing a climate tax on food products as an economic incentive could also be an option for reducing the consumption of livestock products with higher emissions (e.g., beef), possibly leading to emission reductions (Gren et al. 2019). However, penalising the consumption of ruminant meat fails to acknowledge that ruminant systems use less land, which can produce human edible crops, compared to monogastric systems on a per unit of nutrient basis (Lee et al. 2021). Furthermore, a tax on

ruminant meat carries socio-economic risks such as reduced human wellbeing due to forced re-allocation of land and labour, and an economically sub-optimal use of available land resources (ibid.). The current influence of EU policies on food consumption is low, also because measures relating to demand are realised at the Member State level and while there is, for example, some consensus on the messaging required to reduce meat consumption, recommendations for specific reduction amounts differ among Member States (Guyomard et al. 2021; Springmann et al. 2020).

Animal welfare Changes in production structures and practices have impacted animal welfare in the EU and intensification processes have led to growing animal welfare issues in some regions (Läpple and Sirr 2019; Noll et al. 2020; Muñoz-Ulecia et al. 2021). While extensive systems, e.g. agroforestry, can raise animal welfare levels while also benefitting other environmental parameters (Burgess and Rosati 2018), animal welfare improvements are often context specific (Brennan et al. 2021).

Over time, animal welfare matters have been included in reforms of the CAP (Leone 2020) and including animal welfare into the conditionality of Pillar I payments in the recent CAP reform further strengthens the standing of animal welfare matters (ibid.). However, for some commonly kept species such as dairy cows and turkeys, concrete legislation on living standards is still missing, and generally low enforcement rates present an obstacle to increased animal welfare across the EU (Leone 2020).

While cross compliance regulations were successful in influencing farm practices regarding the implementation of animal welfare and food law, some intensive livestock systems do not receive direct payments and are thus not required to fulfil cross compliance regulations (European Commission 2022b). Furthermore, measures under the Rural Development Programme have been successful in improving animal welfare practices particularly around health management and housing (ibid.). The growing consideration of animal welfare aspects in the CAP is a positive development as it can both increase public trust in EU legislators by recognising the growing public awareness for animal welfare matters, and support farmers in reacting to increased public expectations (Leone 2020). However, based on the evidence reviewed by the European Commission, the effect of the CAP on improving animal welfare seems limited to certain locations and sectors, with the cattle sector making more use of available support and thus making greater improvements than the poultry and pig sector (European Commission 2022b).

The option given by recent CAP reforms to include further labelling systems for animal welfare standards, as currently only required for table eggs, would increase the transparency of livestock production, enabling consumers to make informed purchasing decisions and work as an incentive to make (technological) improvements for greater animal welfare (Leone 2020), and can incorporate wider environmental outcome categories (Duvaleix et al. 2020). To support transparency on animal welfare through labelling, it thus becomes necessary to establish animal welfare as a part of sustainability assessments, that are practical but sound and capitalise on potential advantages of outcome-based indicators (Brennan et al. 2021; Krieger et al. 2020).

However, balancing this with the ability of and incentives for farmers to comply with animal welfare enhancing measures is crucial for successful delivery. Low levels of motivation and/or skills regarding animal welfare management could become an issue for compliance with EU policies (Grodea 2020); and higher payment rates to compensate for improvements made are necessary (Vissers et al. 2021; Schermer et al. 2016).

Economic impacts

Farm and production structure Farm structural changes observed through CAP reforms are mostly related to the intensification and simplification of production. In extensive systems, such developments can lead to the cessation of production and land abandonment, if investment costs needed to comply with stricter regulations (e.g., on animal welfare) are too high (Schermer et al. 2016; Horrillo et al. 2016). While in some countries a concentration of production on fewer farms can be observed, a decline in livestock production and/or land abandonment is common in others, especially in Eastern countries following EU accession (Némethová and Hudáková 2019), sometimes exacerbating already existing disparities between regions (Némethová et al. 2017). While this can create unwanted consequences for other sectors, e.g., when less manure is available for fertilisation (Némethová and Hudáková 2019), the administrative load and eligibility criteria related to the implementation of CAP measures also benefits specialised systems over their traditionally lower-intensity counterparts (Jitea et al. 2021).

One of the biggest drivers for structural change in the dairy sector in the last decade was the abolition of milk quotas in 2015, which has resulted in decreasing dairy herds due to lower prices (Läpple et al. 2022). In Belgium, dairy farm sizes and production increased and the organic sector grew between 2016 and 2019, while farms with less than 60 cows ceased to operate (Lessire et al. 2019). The dairy sector in Ireland and the Netherlands expanded and production increased through a growing of herd sizes and increased stocking rates (Läpple and Sirr 2019). Dutch farms that intensified production recorded below average economic performance whilst Irish farms show above average results (ibid.). This is in line with Gaudino et al. (2018), who find

that reaching economic sustainability is difficult for Dutch dairy farms due to energy costs increased outpacing price gains (Oenema et al. 2011). However, Martinho (2020) stresses that price changes after the quota abolition are not attributed to the CAP, but rather a result of cyclical behaviours and market volatilities. Similar results are reported by Kranjac et al. (2020) who state that the benefits of Croatia's EU accession that became apparent after some years were less the results of CAP measures per se but rather the result of prices on the single market.

Labour While farming is a profession that for many is connected to a sense of pride over being independent and owning a business (Key and Roberts 2009), it can also return low incomes for high labour demands, making it unappealing to young people (Belanche et al. 2021). In this regard, agricultural subsidies are seen as important in supporting farmers' incomes and rural communities as they help maintain jobs (Valach 2021), and support young farmers taking farm ownership for the first time (Pavić et al. 2020). Authors found statistically significant positive effects on dairy farms' workforce, revenue and net value added, while also leading to increases in herd sizes in Slovenia (ibid.). Authors further found a link between herd sizes and farmer education, with farmers holding college degrees having significantly more livestock than colleagues without degrees (ibid.).

Payments and subsidies The impacts of payments dominates the discussion around the economic impacts of EU policies on the livestock sector. As Guyomard et al. (2021) point out, livestock production in Europe is confronted with issues affecting all sustainability dimensions and the possible positive outcomes of livestock farming are prevented by an economic situation that does not allow farmers to make changes. At the same time many authors stress the importance of subsidies for income support, and that these businesses can help to stabilise food production and support rural communities (Olagunju et al. 2020; Pavić et al. 2020; Ivanov 2020; Valach 2021).

Yet, even with payments, incomes in some regions and farming systems are still too low, so that farmers might advise their children to take up other forms of employment (Noll et al. 2020) or may look for other ways to increase income, e.g., by converting to organic farming (Horrillo et al. 2016). Critically, this step of making changes to the system when is no longer economically viable may be prevented by subsidies which may hinder adaptation and innovation (Valach 2021) and lead to a culture of dependence, in particular for some extensive grazing systems (Ragkos et al. 2017; Horrillo et al. 2016).

Milk quotas helped maintain dairy production in less competitive regions with lower efficiencies and on smaller farms (Schermer et al. 2016; McDonald et al. 2014; Salou et al. 2017), but they also had a constraining effect on more productive regions and farms and may have even limited young entrants into the dairy industry (Institut d'économie industrielle 2008; Dillon et al. 2005). At the same time, the removal of dairy quotas led to an increase in milk production across the EU (Salou et al. 2017), which was achieved both by increases in herd sizes and milk yields (Brennan et al. 2021). When the quota was finally abolished in 2015, concerns were raised about a new increase in supply decreasing market prices (Martinho 2020) as seen in France (Salou et al. 2017) where the removal of quotas contributed to a cessation of milk production, and an increased risk of abandonment of less accessible land (Schermer et al. 2016). However, Salou et al. (2017) do not find that quota abolition has led to a significant shift in dairy production systems in France and even when taking into account changes in global market demand, the extent of redistribution of production towards more efficient farms is still relatively small.

At the same time, farms taking part in agri-environmental measures may not receive adequate compensation for declines in productivity (Jitea et al. 2021; Kilgarriff et al. 2020). In this case, environmental measures designed to support extensive techniques and thereby maintain farming systems cannot compete with off-farm income opportunities (Jitea et al. 2021). While direct payments can have a substantial influence due to farms' dependency on them (Schermer et al. 2016), voluntary environmental schemes may become more appealing if premiums are raised, notably in regions of high intensity (Früh-Müller et al. 2019).

Common Agricultural Policy payments have also been influential in shaping production structures, e.g. through decoupled payments favouring crop production in Croatia (Kranjac et al. 2020). Such payments have also influenced individual farms' production orientation and outcomes, through impacting the price of farmland (Olagunju et al. 2020) and payments under the first pillar of the CAP are considered as a central cause for the intensification of extensive farming systems (Plieninger et al. 2021). This intensification took place for example through slaughter premiums for fattened livestock leading to a rise in on-farm fattening (Veysset et al. 2005; García-Martínez et al. 2011), increases in herd sizes, reduction of labour and growing capital intensity (Muñoz-Ulecia et al. 2021). Grodea (2020) found a positive impact of coupled payments on the herd sizes and meat production of goats and sheep in Romania under simultaneous concentration developments. However, Ivanov (2020) did not find that direct payments and subsidies had a large effect on livestock production increases in Bulgaria, and Sarov and Kostenarov (2019) conclude that while CAP payments impacted gross margins and profit, they had no impact on farms' production structures in Bulgaria.

Several authors report on the positive impact of decoupled payments on the productivity and efficiency of farms (Olagunju et al. 2020), which could be related to the income support generated through such schemes, which could allow farmers to gain better access to credit for investments to improve production processes and farm management (Martinez Cillero et al. 2018; Olagunju et al. 2020; Bertolozzi-Caredio et al. 2020). At the same time, Alexandri et al. (2020) conclude that subsidies do not necessarily contribute to an increase in productivity as they may limit the competitiveness of farms. It is thus difficult to draw overarching conclusions on the effect of decoupled payments on agricultural production.

Governance

The 'governance' category of the SAFA guidelines was the least represented in the literature, although it can be argued that governance principles are reflected in the other three categories to some extent (FAO 2014). Where governance impacts are more explicitly described, this is in relation to pressures that changes in the CAP framework have meant for farmers, e.g. with regard to payments access (Ragkos et al. 2017). It is acknowledged that while the CAP over decades of reform has changed to include wider societal objectives, food security remains the CAP's core aim (Schulte et al. 2019). While this focus has resulted in a decoupling of food production from other ecosystem services (Schermer et al. 2016), the challenges and risks of transitioning towards greater sustainability thus needs to be shared by policy rather than shifting responsibility on farmers alone (de Olde et al. 2017).

What are reasons for failure or delays in reaching sustainability objectives in the livestock sector?

It may not be surprising that several challenges preventing a more sustainable livestock sector in Europe persist despite the increasing focus of policy and research on this issue. As Abson et al. (2017) point out, changing and assessing parameters (e.g., subsidies, targets on protected areas) only has limited potential for system change.

Even though the last CAP reforms, through greening requirements or agri-environmental measures, have increasingly focused on improving the sustainability of farming systems and businesses (Martinho 2020), livestock farms across the EU are still faced with a set of significant issues regarding environmental impacts (e.g., GHG emissions, nutrient imbalances causing pollution), agricultural land expansion at the cost of natural areas, and increased concerns regarding farm animal welfare (Guyomard et al. 2021).

Lack of regulation

"Re-structure" is the area of "deep leverage" that was most represented in the reviewed literature (Table 2), either by discussing the importance of values and normative understanding or needed changes in the regulatory framework. A possible reason for this could be the overlap of this leverage category with assessing parameters and feedbacks of the food system and its policies, which is a major focus of the scientific debate around sustainability of food systems (Abson et al. 2017). Lacking regulation is described in the context of extensive production models, animal welfare issues, digitalization and environmental protection. Some authors conclude that the absence of specific rules for extensive farming practices (e.g., agroforestry) within organic regulations is limiting farmers' ability to distinguish their systems from others, making a transition to organic farming less attractive (Horrillo et al. 2016; Ragkos et al. 2017). Authors furthermore criticise the inadequacy of existing regulations in reducing livestock numbers to reduce environmental problems linked with high phosphorus loads (Garske and Ekardt 2021), and reach targets set by the Paris Agreement (Stubenrauch et al. 2021). This highlights the challenges linked to increased manure amounts, decreased manure quality and the associated impacts on soil biodiversity (Köninger et al. 2021). Other areas described as needing enabling positions are using food waste as animal feed (zu Ermgassen et al. 2016), and the design of measures supporting digitalisation on farms (Garske et al. 2021).

While some authors call for stricter regulation that aligns with environmental targets (Stubenrauch et al. 2021), others also see the dispersion of regulating frameworks across different legislations as complicating progress (Köninger et al. 2021). Köninger et al. (2021) identify eight EU policies that are dealing with different aspects of manure management and treatment in the EU, yet a comprehensive piece of legislation combining the different parts is missing. This can be problematic if it creates an impression of an ever-changing legislative setting, as this can lead to low compliance (Stuhr et al. 2021). Lacking regulation on animal welfare is criticised with regards to missing legislation on living conditions of some livestock species, an inaction to follow scientific recommendations by the European Food Safety Authority and a low rate of enforcing existing laws (Leone 2020). Regulating animal welfare legislation on a supranational (i.e. EU) level is important as this can guarantee a level-playing field for all actors and avoid unfair treatment of farmers in different Member States with different standards (Guyomard et al. 2021; Öhlund et al. 2017). Similar approaches could be adopted to meet the demand

for EU wide indicators for soil biodiversity (van Leeuwen et al. 2017).

Lack of concrete targets and enforcement

Most criticism in relation to targets concerns the lack of detail on measurable outcomes (Larkin et al. 2019), or aspects of universality (Ragkos et al. 2017), e.g., neglecting site-specific conditions when it comes to the capping of nitrogen application rates or livestock densities (Garske and Ekardt 2021). This lack of consideration for local characteristics and farmers' knowledge can result in low rates of compliance with nitrogen reducing practices (Stuhr et al. 2021). Difficulties also arise from conflicting targets, e.g., between agri-environmental measures and the CAP objective of 'competitiveness' (Garske et al. 2021).

A challenge with regards to target definition concerning manure is the lack of unity across Member States, e.g., on defining manure quality, or the significance of soil biodiversity (Köninger et al. 2021). Greater emphasis is also required by Member States in improving basic measures of the Water Framework Directive to further deliver on reducing diffuse pollution (Kilgarriff et al. 2020). The enforcement of practices and compliance requirements are further problems (Garske and Ekardt 2021; Kuhn et al. 2020; Guyomard et al. 2021), which have contributed to unfulfilled environmental objectives within the Nitrates Directive (Köninger et al. 2021) and beneficial landscapes features of Pillar I payments (Burgess and Rosati 2018).

Current policies like the EU Green Deal follow an ambitious sustainability agenda, with objectives for farming and food systems, the environment, climate and health, including concrete targets for farming, for example on a reduction of fertiliser and antibiotic used as well as increases in protected areas and organic farming (Guyomard et al. 2021). However, some farm types only showed limited environmental improvements (Cortignani and Dono 2018) despite sustainability objectives in previous CAP reforms (Martinho 2020).

The incorporation of local rules and values can help to compensate for top-down governance side effects and ensure an equal consideration of economic and social system aspects (de Olde et al. 2017; Ostrom 2009). At the same time, authors also welcome the move away from a "one-size-fits-all approach" to regulation and incentives, e.g., within the Water Framework Directive or in the design of agri-environmental schemes in the post-2020 CAP that allows for more locally targeted measures (Kilgarriff et al. 2020). Adding quality parameters to assess the performance of the ecological focus area (EFA) measure would mean a move towards a result-based approach in accounting for successful policy implementation (Larkin et al. 2019), and consequently a fundamental shift in the regulatory system.

Exclusion of farms

Another hindering factor for the wider adoption of more environmentally friendly practices are narrow inclusion criteria, that can discriminate against farmers or production areas. This can result from policies overlooking the heterogeneity of livestock farms, as illustrated by the various definitions of permanent grassland under Pillar I payments, which exclude shrublands, even though they were traditionally grazed in Greece and thus affect a large number of livestock farms (Ragkos et al. 2017). In Romania, small-scale farmers also felt disadvantaged by the CAP eligibility rules for Pillar I payments on minimum plot sizes (Jitea et al. 2021). At the same time, measures for Ecological Focus Areas exclude over 48% of the farmed EU area due to a minimum land area requirements (Schulte et al. 2019). In Germany, the uptake of agroforestry was constrained by bureaucracy requiring farmers to divide fields in areas with and without trees, complicating the application for Pillar I payments (Burgess and Rosati 2018). Bureaucratic requirements can also work directly against what makes sense for the individual environmental circumstances, e.g., when prescribing management measures under agri-environmental agreements (Schermer et al. 2016).

Unattractive conditions for agri-environmental measures or Pillar I payments can also create a great bureaucratic load, and insufficient advice or information, and low payments that do not compensate farmers adequately, can create barriers to the uptake of more environmentally friendly practices (Jitea et al. 2021; Guyomard et al. 2021; Popovici et al. 2021; Schermer et al. 2016). Uptake of organic farming can also be hindered by unattractive payment rates related to the small CAP budget devoted to the sector (Stubenrauch et al. 2021). Criticism of Pillar I payments also raise issues of missing education provision that encourages successful farm strategies that do not rely on payments (Noll et al. 2020) and a too narrow focus on monocultures and profitability within the CAP (Plieninger et al. 2021).

Limitations of the review

This review set out to compile the scientific evidence on how EU agricultural policies impacted the livestock sector on different sustainability dimensions. The focus on policies within the CAP was not intentional, but rather evolved from the papers per se. We are aware of the limitations this imposes on the "completeness" of the impacts, e.g., the question of additionality in implementing agri-environmental measures, is not extensively covered, but

this is a dis-incentive to farmers already applying more nature friendly methods. Some authors propose to extend the EFA measure by habitats not currently covered by cross-compliance (or conditionality), or to consider the quality of habitats instead of quantity (Larkin et al. 2019). Nevertheless, the gathered material allows for a reflection of how impacts and issues are linked to the three leverage points described by Abson et al. (2017) and thus relate to fostering or hindering transformative change in the livestock sector. At the same time, the small number of papers relating to the Leverage Points concepts points towards a research gap of considering change in livestock sector rather than providing an assessment of the current state of systems. We furthermore acknowledge the fact that the framing of farm animals as "livestock" in this review may have limited findings especially related to reconnecting with the natural world under the leverage concept or the One Welfare approach.

Conclusions

A review of peer-reviewed papers of the impacts of EU agricultural policies on livestock systems has revealed the following insights:

- Economic and environmental aspects are covered more by the assessed literature than social topics, which may be linked to a lack of agreement on what these entail and how they should be measured.
- Changes to production structures are not homogenous within the EU. Consolidation, specialisation, and intensification are occurring simultaneously with decline and abandonment, e.g., due to eligibility criteria of some CAP measures, specialised systems benefit more than diverse ones.
- The positive relationship between farm size and payments received is an incentive to increase the size of farms and drives intensification, yet this is highly context specific. Payments for voluntary environmental schemes are often too low. Thus, increasing premiums can work as an incentive for greater uptake, especially in high-production areas.
- Maintaining a farming identity is often perceived as desirable even if economically unviable. This identity helps to stabilise food production and supports rural communities. Yet, dependence on subsidies, especially for small-scale extensive systems can prevent necessary innovation.

The various CAP reforms have had a particularly negative impact on the sustainability of the livestock sector in the EU. They have contributed to intensification and simplification, the increased use of external inputs, changes in grazing and pasture management as well as breeds and increased stocking densities, often with negative impacts on the environment and animal welfare. More recent EU policy reforms have focused increasingly on improving the sustainability of farming systems, however due to a lack of regulation, enforcement, farmer support, willingness of policy-makers, concrete targets or target inconsistencies; as well as the exclusion of farmers, livestock farming in the EU is still linked to issues across all sustainability dimensions.

This can be related to a focus on shallow interventions such as cross-compliance regulations or conditionality, environmental focus areas for protection, or agri-environmental payments, which are unable to trigger profound changes. This limited approach is paired with scientific analysis which often focusses on single aspects and favours the measurement of material flows and feedbacks. Since greater impact for system change is attributed to changes of its intent, it is worth underlining that the current challenges related to livestock farming are also linked to a shortfall in addressing this intent by policy and science alike. Currently, clashes between human, animal and environmental interests are limiting progress towards developing and reaching binding sustainability targets. It seems obvious that the lower level interventions that are currently observed will not be sufficient to resolve the environmental, economic and social challenges facing European livestock systems, which calls for an urgent and rigid reflection on the scale and proportionality of human demands on the food system.

Overall the systematic review of studies on the impact of EU agriculture policies on livestock farming shows gaps in research and policy in terms of holistic sustainability concepts. Furthermore, it highlights the importance of integrating holistic worldviews in policy design – to ensure that the relationships between human interest(s), nature and farmed animals are represented and acted on accordingly

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