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Review

Structured Analysis of Livestock Farming Practices and European Green Deal Targets

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Abstract

The European Union (EU) Green Deal (EGD) aims to significantly transform and modernize the EU economy, while at the same time envisioning significant changes in agricultural production, especially in livestock farming. Generally, EU Member States implement specific measures that contribute to the achievement of various EGD objectives. Most often, these are part of the national strategies of the EU Common Agricultural Policy. At the same time, it is important to identify the available scientific information on measures that contribute to the achievement of the EGD goals and their various impacts. Usually, each individual measure or practice is aimed at achieving one of the ESD goals, for example, reducing GHG emissions, but in practice, these create multiple side effects that can promote or hinder the achievement of other sustainability goals. This study focuses on the livestock sector and outlines key areas where intervention must occur: feeding, housing, grassland/pasture management, manure management, breeding and genetics—these factors interact and contribute to the achievement of EGD targets. At the same time, this research takes a holistic view of the EGD demands on livestock. In this study, the authors use pictograms and a color-coding system that broadens the scope of impact communication. It translates complex, scientific data into a format that is accessible and easily understood by a wider audience. The results of this study reveal that systematic research is needed to examine livestock farming measures that could change agricultural policies in the long term—from supporting existing measures to creating appropriate sustainable farming systems.

Keywords: EU Green Deal; sustainable livestock; structured analysis; livestock farming practices

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1. Introduction

The European livestock sector stands at a critical juncture, confronting an existential sustainability challenge; this can be characterized by a multitude of socio-ecological issues and both discursive and legislative pressure to change. In addition, it must satisfy escalating global protein demands while reducing its substantial environmental footprint. Agriculture generates 30% of the European Union's greenhouse gas emissions, with livestock production responsible for over 80% of this burden, primarily through methane emissions [1] and nitrous oxide emissions from manure and fertilizers. While the possibilities for reducing these emissions are rapidly increasing thanks to effective changes mostly in intensive production systems [2], these systems are simultaneously fueling exceptional biodiversity loss [3]. Biodiversity is being lost in several ways. There is rapid replacement of local,

regional and less productive livestock breeds with one or a few "global" elite breeds. Local breeds are often better adapted to local climates and more resistant to local diseases, but they are being pushed out for economic reasons. In addition, to support intensive farms, areas for growing fodder (e.g., maize monocultures) are being expanded, destroying natural ecosystems such as wetlands or natural grasslands. Other risks are related to the loss of organic matter and greenhouse gas emissions, the excessive use of fertilizers, and erosion, pollution, acidification, and salinization [4]. At the same time, the sector plays a critical role in the economy of EU countries, providing over 4 million jobs and securing the food security of almost 450 million people [5]. Structural impediments, such as fluctuating global commodity markets, favor short-term productivity over long-term sustainability. A further issue is that the aging farming population, more than 55% of whom are over 55 years of age and are reluctant to embrace new methods or systems, also obstructs any meaningful transformation [6]. At the same time, research on sustainable livestock practices remains fragmented across three traditionally isolated dimensions (economy, environment, social), limiting holistic solutions where the "human dimension" is central [7]. Production-focused studies quantify single practice impacts such as the potential of rotational grazing for storing carbon (0.5^{-1} ton C/ha/year in well-managed pastures) and of anaerobic digestion for reducing methane production from manure by 60% [8]. The overlap of the effects of practices and their significance in the wider ecosystem is not modeled equally [9]. Instead, the environmental impact assessment looks at isolated results such as reductions in greenhouse gas emissions but fails to consider the wider socioeconomic implications [10]. The Farm to Fork Strategy's target of a 50% reduction for pesticide use, for example, may reduce levels of chemical pollution while increasing production costs by around 15% [11], which risks farm viability in the absence of strong replacement measures or market supports. Policy analyses rigorously critique CAP eco-schemes and greening requirements yet rarely examine how subsidy structures [12], environmental regulations, cross-compliance mechanisms, and international trade policies dynamically interact to enable or hinder transitions at regional scales [13]. Yet it is precisely this ongoing compartmentalization that has led to crucial knowledge gaps with respect to practice interdependencies, such as the integration of manure digestion and agroforestry systems [14]. It should be noted that in combination, these factors synergistically enhance the overall impacts on biodiversity beyond their respective standalone contributions [15], and regional scalability impediments explain why for example German vs. Bulgarian farms differ by 10-fold in the adoption of renewable energy, despite very similar climatic conditions. Importantly, the behavioral drivers of farmer decision making are underexamined [16], yet there is substantial evidence that the well-being of 70% of dairy farmers has improved dramatically after adopting sustainable practices [17].

The European Green Deal (EGD) positions livestock systems as central to achieving the EU's legally binding climate neutrality objective by 2050, with stringent 2030 targets demanding nothing short of transformative change across the sector [18]. The Farm to Fork Strategy stipulates that 25% of farmland must be organic, that fertilizer use should decrease by 20% and that pesticide risks need to be reduced by 50%, while the Biodiversity Strategy requires that 10% of agricultural land be set aside for high-diversity landscape features, as shown in Figure 1. Cattle farming, which accounts for 73% of livestock methane emissions, is particularly noticeable by its absence in recent changes to the Industrial Emissions Directive relating to livestock pollution [19].

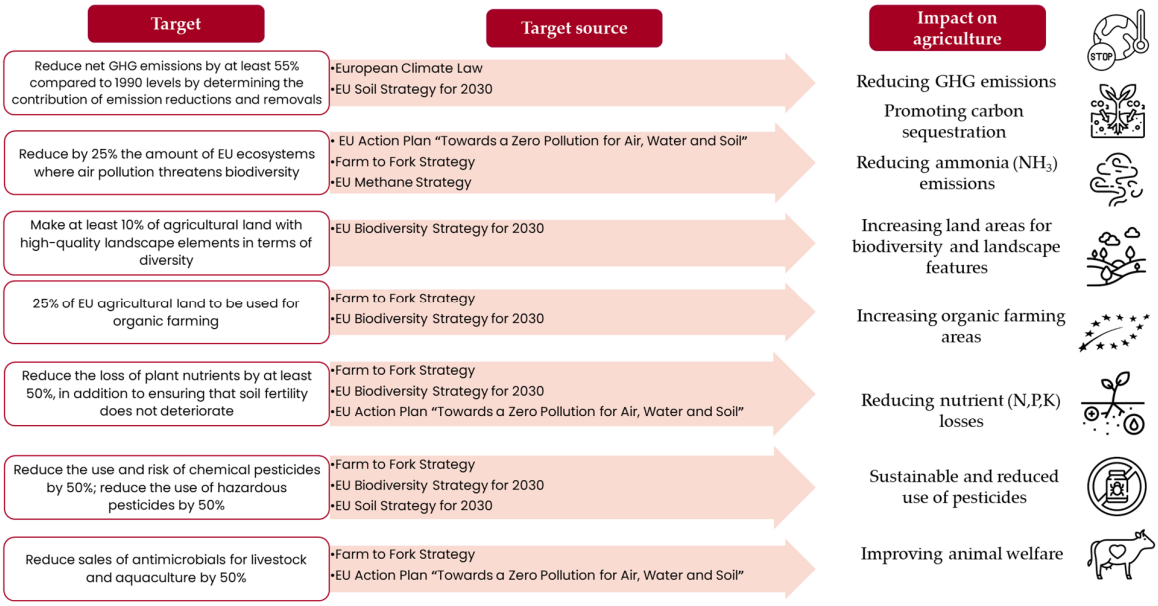

Figure 1. EGD target indicators and their sources and impact designations.

Ambitious plans mean that there are likely to be conflicting goals, with reducing methane emissions likely to increase ammonia emissions, for example, or reducing pesticide use leading to reduced productivity. At the same time, there are also contradictions within the EU. There are significant regional disparities, suggesting that the allocation of CAP funds is uneven in its impact across regions. The implications for policymakers are clear: a more tailored approach is required to enhance the effectiveness of CAP funds in meeting diverse regional needs, particularly in promoting economic development while minimizing environmental harm [20]. A worrying trend is evident; EU meat production is decreasing, while 80% of future meat growth is attributable to Latin American and Asian countries, where integrated (environmental, economic, and social impact) assessment is not fully implemented [21]. The EU's New Open Strategic Autonomy Policy, using a carbon border adjustment mechanism, requires the inclusion of carbon tariffs on goods such as cement, electricity, fertilizer, steel, etc. [22]. At the same time, it must be acknowledged that the mechanism is far from perfect and does not solve many problems related to the import of agricultural products from countries with different carbon pricing policies [23].

This research aims to evaluate EGD targets through their specific impact on main livestock practices (feeding, housing, grassland/pasture management, manure storage and treatment, animal breeding and genetics) and seeks to understand the feasibility, effectiveness and consequences of achieving EGD goals—such as reductions in greenhouse gas (GHG) and ammonia emissions, nutrient losses, animal welfare, etc., by focusing on the practical on-farm changes required in the livestock sector.

2. Materials and Methods

2.1. Research Framework and Data Sources

The first step of this study was based on the identification of the European Green Deal target indicators and sources from which these indicators were derived. In total, eight targets were identified, stemming from six strategic documents. For each target, the specific impact on agriculture was identified (Figure 1).

The second step of this research was the selection of livestock practices. As the foundational vocabulary for practice categorization, the classification scheme developed by the Joint Research Centre [24] was used. The following five groups of practices—animal feeding;

animal housing and welfare; grassland and pasture management; manure storage; animal breeding and genetics—were aligned with and nested within the Joint Research Centre's hierarchical classification tiers. This ensures standardized comparison and aggregation.

2.2. Analysis of Practice and Impact Evaluation

Following this, each practice was rigorously assessed for its quantitative and/or qualitative impact on various processes and indicators relevant for EGD. For indicators where numerical data were robust (e.g., GHG emissions, nitrogen leaching, feed conversion efficiency), the impact was quantified via structured literature analysis of the peer-reviewed literature, where in most cases, results were expressed as a percentage change relative to the business-as-usual baseline. For indicators or processes where quantification was challenging (e.g., specific aspects of biodiversity, soil structure, animal welfare improvements), the impact was determined through a systemic expert judgment process based on the synthesis of non-quantitative technical reports and regulatory requirements.

2.3. Data Visualization and Synthesis

To synthesize and communicate the complex, multi-dimensional impact of each practice group, a specific visualization approach was developed.

A unique pictogram was selected for each specific impact type, and a standardized color-coding system was assigned to each pictogram, reflecting the nature of a given practice's impact on the corresponding process (Table 1).

Table 1. Pictogram selection and color-coding system used in this study for visualizing impact effect on EGD targets.

Pictogram	Impact	Meaning of Pictogram Color			
		Positive Effect	**Neutral Effect**	**Negative Effect**	**Unclear Effect**
	Reducing GHG emissions				
	Promoting carbon sequestration				
	Reducing ammonia emissions				
	Increasing land areas for biodiversity and landscape features				
	Increasing organic farming areas				
	Reducing nutrient (N, P, K) losses				
	Promoting sustainable and reduced use of pesticides				
	Improving animal welfare				

In the developed color-coding system, pictogram color reflects the results from the structured analysis of peer-reviewed literature concerning the quantitative and/or qualitative effect of livestock practices on the relevant impact of different dimensions of EGD.

- **Green** indicates a positive effect, which is confirmed by the analyzed literature reporting a positive impact change relative to business-as-usual baseline;
- **Gray** indicates a knowledge gap, i.e., some evidence was found on the effect of livestock practice on a specific type of impact;
- **Orange** indicates a negative effect, which is confirmed by the analyzed literature reporting a negative impact change relative to the business-as-usual baseline;
- **Blue** indicates an unclear effect, highlighting conflicting and divergent evidence regarding the effect of the practice on meeting EGD targets.

The framework of the structured analysis, the evaluated parameters and collected information, which further served as a basis for visualizing the obtained results in pictograms, are summarized in Supplementary Materials (Annex S1).

3. Results

This section examines important livestock-farming practice groups through the lens of their documented impacts on European Green Deal (EGD) objectives. Five essential links in the European Green Deal have been identified: Transition to a Circular Economy, Sustainable Resource Management, Technological Innovation, Policy Reforms and Empirical Research, and Data-driven Policy [25]. The analysis integrates findings from empirical studies, policy assessments, and technological innovations, emphasizing interdependencies between practices and their cumulative effects on environmental, economic, and social sustainability.

3.1. Animal Feeding Practices

Animal feeding practices that could reduce GHG and ammonia emissions, improve or maintain productivity, and contribute to other Green Deal goals can be divided into three groups—the first is related to feed quality and ration optimization; the second is related to the use of feed additives in prepared feed; the third is related to the introduction of on-farm feed, which is possible in extensive farming systems.

Optimizing feed efficiency remains foundational through established practices like improved forage quality [26], such as legume inclusion in silage, which minimizes the methane produced in the enteric fermentation process and improves feeding methods according to animal requirements [27], thus reducing nitrogen excretion [28] and is essential to improve livestock health, productivity and milk quality, which directly affects animal health [29]. In every dairy farm, the accuracy of animal feeding is related to the farm's economics. An unbalanced diet can cause economic losses, because low fat content in milk indicates the cow's inability to consume sufficient amounts of roughage; if it is below 3.50%, milk production is uneconomical, as too much concentrate has been used, and a fat content of above 4.50% may indicate a lack of energy within the feed rations. The above relationships confirm the need to balance the provision of protein and energy in animal feed and to seek solutions on farms that increase the efficiency of feed utilization, while also ensuring optimal N use on the farm, without creating a surplus that causes GHG or ammonia emissions [30]. Reducing crude protein (CP) intake by 1% can increase feed conversion ratio by 1.3% thus making a significant contribution to reducing GHGs through The same CP reduction decreased daily nitrogen (N) excretion by 10.4%, whereas CP did not affect N retention [31]. According to the authors' calculations, using the "NorFor" methodology [32], reducing CP feeding by 1% reduces ammonia emissions by 3.7% and N_2O emissions by 18% in dairy cows. Moreover, the reduction in ammonia emissions

is characteristic of all stages of lactation, averaging 20–30 g kg^{-1} DM [33]. For livestock production, where poor quality forage is commonly fed, improving grazing management and diet quality can reduce methane (CH_4) emissions by 11% and 5%, on average [34].

The second category related to animal-feed improvements is the use of feed additives. Dietary supplements can reduce CH_4 emissions further, with lipids (15% reduction) showing significant potential [34]. The reduction in ammonia emissions in ruminants is relatively minor, allowing it to be assessed primarily as a form of methane reduction. Conversely, the ammonia reduction effect in pigs is relatively high at around 20% [35]. The use of algae (*Rhodophyceae*) could also result in a significant decline in methane, reducing methane genesis in cattle by 65% [36]. In livestock farms that use pastures, it is possible to reduce ammonia and methane emissions by growing tannin-rich plants. Tannins reduce methane emissions by 11% for cows [34] and up to 30% for small ruminants (sheep, alpacas, goats) [37]. Dietary tannin additives also reduce ammonia emissions (45.5%) [38]. It should be noted that tannin-rich plants have a beneficial effect on soil structure, the abiotic processes in the soil, and the C/N dynamics in the soil [39], as well as positively affecting biodiversity and pollinators. In addition to tannin-rich plants, several other plants may be grown that can benefit organic pastures, such as sunflowers, which attract beneficial insects, enhancing soil organic matter, or alfalfa, which increases the protein content in feed and fixes nitrogen [40].

New technologies consist of methane inhibitors (e.g., 3-NOP, Bovaer) [41], which are at a very early stage of development and demonstrate a 30–90% potential of methane reduction but are limited by cost-related scalability issues and regulatory delays. The evidence base of impact evaluation is most developed in the areas of GHG reductions and nitrogen use efficiency. 3-NOP reduces enteric methane emissions by 30% [42,43], which affects the carbon footprint of milk, reducing it by 12% [44], and also creates a general opinion that NOP3 reduced GHG emissions by approximately 1 tonne CO_{2e} (GWP100) per cow per year [45]. The evidence of impact evaluation remains underdeveloped in the group of biodiversity co-benefits [46] (e.g., reduced land-use change associated with feed crops) and socioeconomic trade-offs (e.g., the affordability of inhibitors by smallholders). At the systemic level, feed additives add to manure management in terms of pollutant load alleviation [47], but synergies with grassland management (e.g., side effects of the interface between grazing and confined systems) have not been explored in depth [48].

The introduction of on-farm feed is possible in extensive farming systems, provided that additional land is available for production. When total land occupation (LO) was considered, the average surface for producing milk resulted in 1.47 m^2/kg of fat- and protein-corrected milk (FPCM); however, the off-farm land occupation was 0.76 m^2/kg FPCM ($\pm$0.24 m^2/kg). The land occupation per unit of production can be reduced by increasing on-farm feed production, particularly protein components, and to a lesser extent by valorizing byproducts, while not increasing the on-farm N surplus and carbon footprint [49]. Indirectly, this indicates that the use of farm-produced feed reduces GHG emissions if they are accounted for using the LCA approach, which is more common in scientific discussion, but not for policymakers, as it does not contribute to achieving policy goals. However, the feeding strategy to be adopted, and the resulting level of feed autonomy, depend on the land use and production potential (% of PG, capacity to grow grain crops, overall DM yield), which are linked to the local soil and climate conditions, and on the targeted animal performance [50].

In Figure 2, the authors provide a visual summarization of the effects of three different types of animal feeding practices on achieving EGD targets.

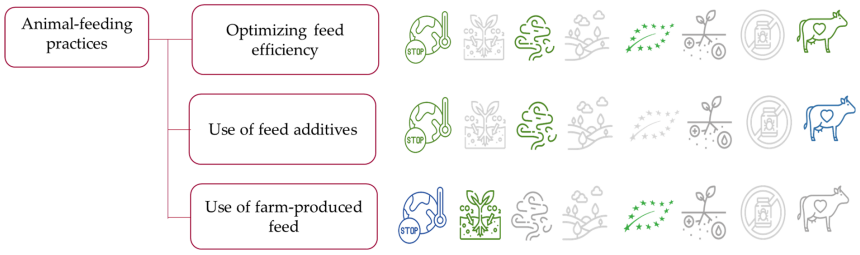

Figure 2. Impact of animal-feed improvement practices on EGD targets (explanations of pictograms and colors are given in Table 1).

3.2. Animal Housing and Welfare Practices

Animal housing practices are related to different improvements in the housing conditions of livestock with the aim of promoting animal welfare. This group of practices fundamentally improves animal welfare, while at the same time, since the production of GHG and ammonia emissions in animals is a complex process, they also indirectly impact other green policy goals, such as reducing ammonia and methane emissions. These practices include access to the outdoors (walking areas), shelters, environmental improvements (such as scratching posts), improvements to the barn microclimate, and lighting improvements. Established practices include ammonia-reducing designs such as slatted floors with scrapers to mitigate emissions and enriched environments [51]. Even the temperature of an animal's housing can affect well-being and productivity and contribute to stress-induced illnesses [52]. New advancements include climate-controlled greenhouses with air filtration that lowers the amount of ammonia and methane; however, this has higher levels of energy usage [53]. Outdoor access is an important welfare factor in intensive cow farms. The impact of intensification on emissions is usually characterized by a reduction in emissions per unit of output, while increasing the load per unit of output. Increasing livestock intensity increases CH_4 ha^{-1} by 26% and simultaneously reduces CO_{2e} l^{-1} milk by 19% [54]. Ammonia reduction using different bedding materials (up to 50%) [55] and improvements in welfare have been studied extensively and results are reliable in terms of impact assessment, but connections to carbon sequestration [56] or biodiversity are less studied and quantified. At the system scale, housing design for animals has a direct correlation with the consistency of manure [57]. In Figure 3, the authors provide a visual summarization of the analyzed animal housing and welfare practices. It can be concluded that measures aimed to improve animal welfare reduce emissions to a lesser extent and do not actually affect the achievement of other sustainability goals.

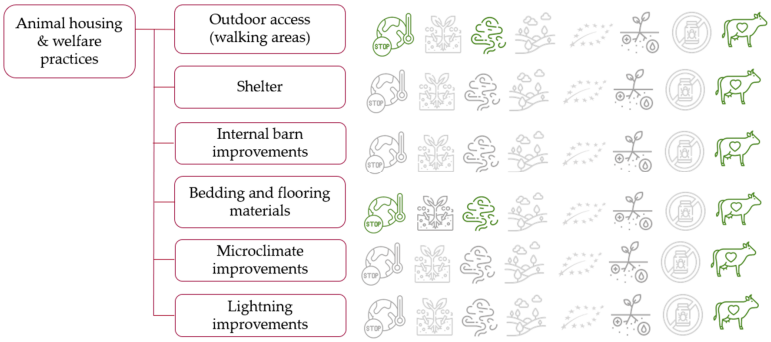

Figure 3. Impact of animal housing and welfare practices improvement practices on EGD targets (explanations of pictograms and colors are given in Table 1).

3.3. Grassland and Pasture Management

Established practices include rotational grazing to preserve soil carbon and reduce erosion, alongside legume incorporation such as clover to provide a fixation of nitrogen

and reduce fertilizer needs [58]. Grassland management has the great advantage of being simultaneously the point of convergence of the carbon buffers for riparian management [59]. It should be noted that allowing cows to graze can reduce methane emissions compared to keeping cows in a barn [60]. However, due to the lower digestibility of feed (grass) compared to concentrates, it was observed that cows raised according to organic conditions produced higher emissions than those in conventional conditions [61]. Grazing management has a positive effect on soil carbon formation and can mitigate GHG emissions [62]. At the same time, a positive effect is observed only with light grazing and close to the soil surface (up to 10 cm) [63]. Grassland management, especially regular reseeding, is also essential to achieve a positive carbon sequestration effect [64]; at the same time, grass cutting increases GHG emissions and reduces carbon sequestration [65]. The type of grassland and pasture management is very important, and extensive management provides advantages and benefits. Therefore, intensity restrictions in pasture management are essential. Managing grazing improves biodiversity and adaptive multi-paddock grazing, which positively affects drought resistance and soil health [66]. Grazing restrictions can reduce both N_2O and CH_4 emissions. Restricted grazing resulted in the more efficient conversion of forage into meat and milk, leading to a 22% reduction in annual projected CH_4 emissions per animal [54]. Intensively grazed pastures are at increased risk of N losses to waterways and the atmosphere. Nitrate losses increase exponentially with increasing animal urine inputs, which affect dissolved organic N [60]. A successful solution that can improve the digestibility of grass feed and the negative effects of intensive grazing is rotational grazing. Rotational grazing can potentially reduce GHG emissions from cow and calf farms compared to continuous grazing [67]. Grazing is an important way of reducing ammonia emissions in livestock farming. This is because urine from grazing animals does not usually mix with feces, so the action of urease on the urea in urine is minimized and ammonia emissions are therefore lower compared to animals kept in sheds or even compared to the non-grazing period [68]. In summary (Figure 4), grazing and grassland management provide many benefits and can be an integral part of sustainable agriculture. The most important condition is the intensity of management, while reduced intensity grazing can reduce GHG and ammonia emissions, improve soil fertility, and increase biodiversity, while intensive grazing has the opposite and often negative effect on sustainability. For example, it has been concluded that increasing stocking rate from a moderate to high level diversity mostly fell within the range 25% or five species [69]; also, grazing intensity had clear effect on vegetation diversity, the effects depending on site-specific vegetation characteristics [70].

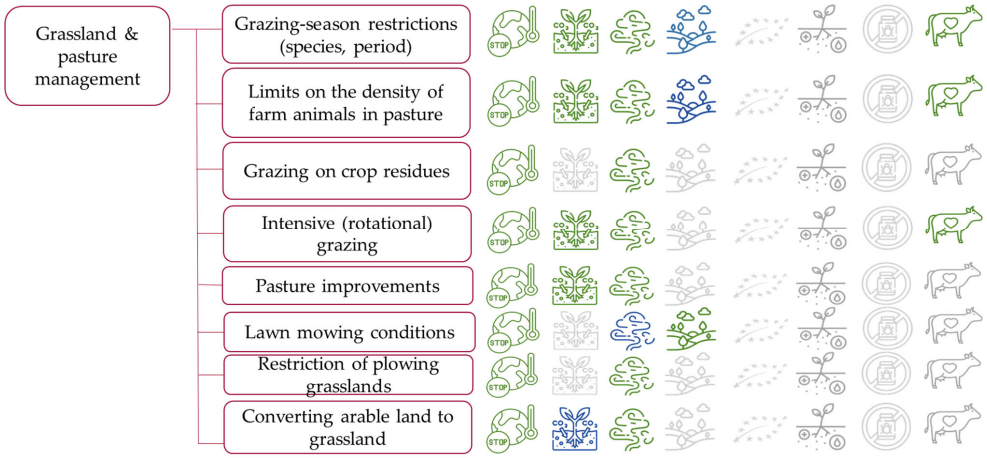

Figure 4. Impact of grassland and pasture management practices improvement on EGD targets (explanations of pictograms and colors are given in Table 1).

3.4. Manure Storage

Research into livestock manure-storage techniques is currently focused on enhancing environmental sustainability, optimizing nutrient retention, and mitigating GHG and ammonia (NH_3) emissions. A key area of innovation is manure treatment with additives [71]. While traditional chemical acidification using mineral acids like sulfuric acid (H_2SO_4) is highly effective—with studies demonstrating a significant reduction in CH_4 (67–97% reductions) and NH_3 (up to 85% reductions) when slurry pH is lowered to 5.5 [72–74]—lower, cost-effective doses and more sustainable alternatives are being developed. For instance, binding agents such as zeolites (e.g., clinoptilolite) have been shown to reduce ammonia emissions by binding ammonium ions, while biochar addition is being studied for its potential to reduce methane emissions in composting piles [75].

A promising path involves natural acids and bio-acidification. This latter technique utilizes agro-industrial by-products or simple fermentable substrates to encourage the endogenous microbial production of organic acids, such as lactic acid or acetic acid, which naturally lowers the slurry pH and suppresses volatile emissions. Effective substrates include readily available, low-cost options like sugar beet molasses, cheese whey, or pure glucose [76–78]. For example, treating slurry with cheese whey has been shown to achieve a NH_3 abatement of over 90% [79]. This method avoids the handling risks and potential soil-sulfur burden associated with concentrated mineral acids.

Alongside chemical treatments, manure topping or covering has evolved significantly, particularly for liquid slurries. Effective methods range from encouraging and maintaining a natural, high-performing crust on cattle slurry to deploying engineered solutions. Research compares the efficiency and cost effectiveness of economical floating materials (e.g., straw, clay granules) against highly effective, yet more expensive, flexible HDPE membranes, all aimed at reducing gaseous exchange, odor, and volume increase from precipitation. In the context of GHG emission reduction, only use of artificial (plastic) film has positive effect on N_2O emissions reduction [80], while all types of covers have positive effect on ammonia (NH_3) emission reduction [37]. For solid manure or farmyard manure, the focus remains on established management practices like the proper compaction of manure heaps [81]. This process helps to create anaerobic conditions, which limit gas exchange and can suppress NH_3 and nitrous oxide (N_2O) volatilization, although advanced chemical methods are less commonly applied to solid heaps than to liquid slurry. One more manure storage technique that attracts attention of scientists is manure cooling, or slurry cooling, which is considered an effective method for reducing emissions, particularly ammonia and, to a lesser extent, certain greenhouse gases, primarily methane [82]. Finally, while not a direct storage technique, manure storage using biofilters is integral to holistic management, often employed to treat exhaust air from livestock buildings or manure processing facilities to control odor and NH_3 emissions before the air is released into the atmosphere.

Visualizing common impacts of different manure storage technologies on achieving the EGD targets (Figure 5), authors conclude that these impacts are mainly related to reducing GHG and ammonia emissions, while impacts on other EGD targets are not broadly analyzed and discussed. This highlights challenges for future research of manure storage techniques—researchers should adopt a holistic, life-cycle approach to fully assess the technologies against all the EGD's environmental and sustainability objectives, moving beyond the current focus on only two targets.

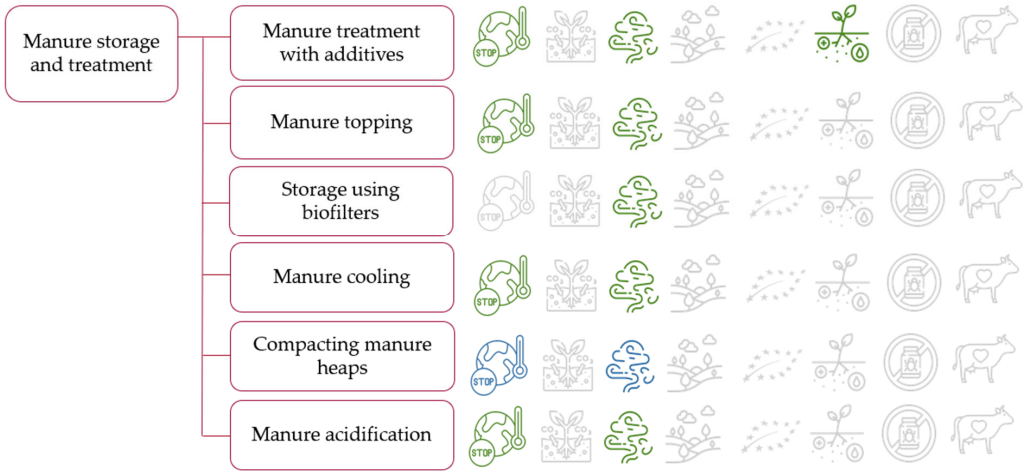

Figure 5. Impact of manure storage practices improvement practices on EGD targets (explanations of pictograms and colors are given in Table 1).

3.5. Animal Breeding and Genetics

The general objective of animal breeding is to create a new generation of animals that, in the economic, social, and environmental conditions of future farms, will yield the desired products more efficiently and will be more resistant to interference than the current generation of animals. In the context of EGD targets, three types of breeding programs can be identified—the selection of animal characteristics to reduce GHG emissions; the selection of animal characteristics for disease resistance; and the selection of animal characteristics for longer life expectancy.

The selection of animal characteristics to reduce GHG emissions is usually aimed at ruminants, e.g., cattle, to reduce the CH_4 secreted during digestion. Since the CH_4 secreted during digestion depends on the amount of feed per unit of production and the rate at which metagenesis occurs during digestion, then the main characteristic that is selected is animals with higher feed efficiency [83,84], i.e., the ability to absorb a smaller amounts of feed while maintaining the same level of production and body weight. Lower feed intake leads to the lower excretion of CH_4, while production and body processes are maintained at the same level as in cows with lower feed efficiency. For example, in the experiment performed with Holstein breed cows, the low-methane-emitting dairy cows saved up to 22% CH_4 when compared with high-methane-emitting cows [84]. The level of feed intake affects the time when the feed remains in the rumen, as well as the volume of the rumen. When the rumen retention time decreases, the amount of CH_4 produced is reduced. High feed efficiency yields differences in behavior and digestion, which leads to changes in microbial communities. This causes the transition from acetate to propionate, which reduces the amount of hydrogen available for the formation of CH_4.

Sick animals consume more feed and water but grow more slowly. If an animal is lost due to illness, it means that resources must be invested in raising another animal in order to meet market demand. This means that diseases cause higher levels of GHG per unit of milk, meat, and eggs, as more animals and resources are ultimately needed to maintain productivity. For example, for cows, each avoided clinical mastitis case can reduce potential GHG emissions by 58 kg CO_{2e}/case/ton of milk [85]. Thus, the purpose of certain breeding programs is to promote varieties with natural resistance to diseases, thus reducing the need for antibiotics or treatment. Genetic selection for disease resistance is already carried out all over the world: for dairy cattle—resistance to mastitis and metabolic diseases; in pigs—resistance to pig reproductive and respiratory syndrome (PRRS); in poultry—resistance

to Marek's disease and bird flu; in sheep—resistance to internal parasites (worms of the gastrointestinal tract).

In the context of sustainable livestock development and selection of animal characteristics for longer life expectancy, the desired and recommended target is four to five years or more in lactating dairy cows [86]. This extended productive service life is a key strategy from both an economic and environmental point of view of improving efficiency. The most significant impact comes from the fact that a large part of the GHG emissions generated during the life of an animal occur during the period of unproductive rearing (from birth to the first lactation). By keeping a cow in the herd for longer, these "fixed" rearing emissions are broken down to more milk, reducing the emission intensity (CO_{2eq}/kg of product).

The visual summary of identified impacts of different animal breeding programs is given in Figure 6. Authors conclude that this group of practices are powerful, multi-faceted tools that can achieve EGD targets as breeding programs offer a permanent and cumulative way to improve livestock efficiency and resilience.

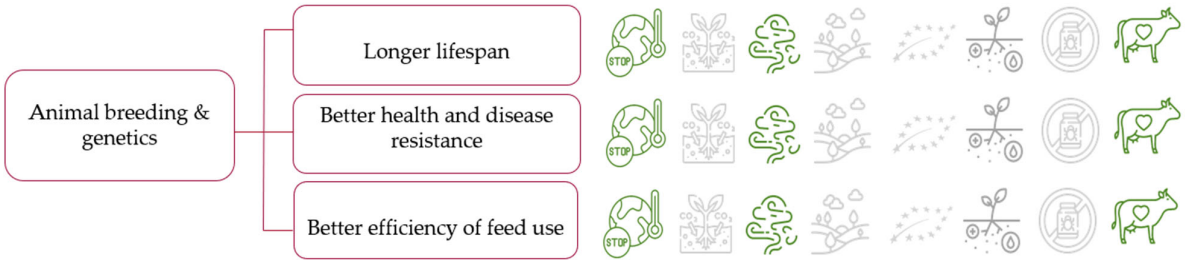

Figure 6. Impact of animal breeding and genetics practices improvement practices on EGD targets (explanations of pictograms and colors are given in Table 1).

4. Discussion on Cross-Cutting Research Gaps and Systemic Challenges

Impact assessment disproportionately emphasizes GHG metrics [87]. Other sustainability factors have been analyzed less, usually associated with common national goals to achieve climate neutrality, consisting of high public-funding intensity (EU CAP support), a common reporting framework (IPCC National Inventory Reports), and proven carbon-market initiatives. In contrast, biodiversity and social impacts have been analyzed less frequently, which reduces the impact of EU policy on the preservation of biologically valuable areas [88]. Typically, the determination of comprehensive sustainable impacts is based on integrated impact assessment, and it should be noted that by reducing negative climate and air quality effects, it is possible to create other significant benefits for society [89,90]. Practice interactions receive little attention, and little has been done to measure multi-practice synergies, such as breeding–feeding interactions [91], on manure composition and soil qualities [92]. The EU's CAP eco-schemes only partially address the trade-off problem, even though the Green Deal policy seems comprehensive. Examples of policy misalignments are eco-schemes in the CAP that lavish practices over systems [12], which are easier to administer and more specifically outline the specific results to be achieved.

The EU Green Deal aims to transform the European Union into a modern, resource-efficient and competitive economy, with a wide range of targets. The European Green Deal (EGD) positions livestock systems as central to achieving the EU's legally binding climate neutrality objective by 2050 [93]. The targets for agriculture include reducing GHG emissions, increasing organic farming areas, reducing nutrient losses, and ensuring animal welfare (Table 2). There are also other objectives that are essential for EU green architecture, as described in more detail in Figure 1. Based on a literature review, some of the most effective practices and co-benefits can be identified.

Table 2. High-impact farming practices for key European Green Deal targets.

EGD Target	Most Effective Practices	Co-Benefits
GHG reduction (−55%)	Optimize feed efficiency, methane inhibitors	Lower synthetic fertilizer use, Improved animal welfare, reduced ammonia emissions (air quality)
Improving air quality (reducing ammonia emissions) (25%)	Outdoor access, bedding and flooring materials	Improved animal welfare, reduced GHG emissions,
Nutrient loss reduction	Grazing season restrictions, limits on the density of farm animals in pasture, rotational grazing,	Reduced eutrophication, reduced ammonia emissions (air quality), improved freshwater biodiversity enhancement, soil organic carbon retention quality, improved animal welfare, biodiversity and landscape elements
Animal welfare	Outdoor access, grazing access, bedding and flooring materials,	Lower antimicrobial use, higher productivity, reduced veterinary costs

From one perspective, efforts can be observed in two directions, which are essentially related to the intensification of agricultural production, reducing negative externalities and extensification or reducing production intensification, which creates greater positive externalities, but causes economic difficulties for farmers. This could mean that two different directions need to be politically supported. For example, integrated organic production with low-intensity pasture management, thoughtful feed management and soil fertilizer management on the one hand, and intensive production with precision and digital technologies [29], methane inhibitors, and tethered livestock keeping, including walking areas, on the other. At the same time, neither direction can ensure the achievement of the EGD targets and the transition to sustainable agriculture on their own, so the challenge is for each member state to determine the appropriate proportion. At the same time, the EU has already determined that organically managed areas should account for at least 25% of the total agricultural area, indirectly indicating that organic farming is essential for achieving this goal. Organic farming can also be efficient and implement modern digital technologies that stimulate the achievement of EU goals, while at the same time requiring changes in laws [94]. It is clear that it is not possible to create policy regulatory or support measures that would be equally effective for all farms as these differ significantly in terms of both their initial characteristics and the way in which possible measures can be implemented, so we should focus on measures for groups of farms typical for each country [95]. Overall, there is a growing argument that a multifaceted approach, encompassing policy, technology, and innovation, is essential for overcoming the challenges of environmental sustainability and climate change. At the same time, difficulties in achieving the goals of the EU Green Deal are caused by the side effects of the implemented measures, as there is a lack of analysis and discussion surrounding these in the scientific literature (Table 3).

Table 3. Research coverage gaps in livestock practice impact studies.

Practice Group	GHG	Biodiversity	Nutrients	Welfare
Animal Feeding	High	Low	Medium	Medium, Low (methane inhibitors)
Animal Housing and Welfare	Medium	Low	Medium	High
Grassland and Pasture Management	Medium	Medium	High	High
Manure Storage	High	Very Low	Medium	Low
Breeding and Genetics	High	Very Low	Low	High

GHG and ammonia emission reduction measures have been studied relatively extensively in the scientific literature, with research differing both in the assessment of the numerical effects and the assessment of overall effects. This provides an opportunity for broader meta-analyses to be conducted, which allows for the comparison and evaluation of diverse studies, creating new deeper understanding and knowledge. The diversity of such information provides an opportunity to assess the progress of the EU Green Deal [96]. However, other effects of these measures on biodiversity have been relatively poorly studied. On the one hand, for example, animal feeding does not directly affect biodiversity at the national level. On the other hand, focusing on imported concentrated feed may have consequences in the country where it is produced, but remain unnoticed if an LCA approach is not used. Systematic studies are needed that would not only track the entire cycle, for example, of nitrogen, but that also examine the impact of measures on all processes affecting agriculture, both on farms and in the wider area. This would provide an opportunity to re-evaluate agricultural measures and practices towards locally appropriate management systems, which should be incorporated into the agricultural policies of the EU Member States. The most popular example of a management system is organic production, which includes both specific conditions, opportunities, and support systems, but an integrated view is needed for the entire agricultural sector, which could provide sufficient information for policymakers and the public.

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